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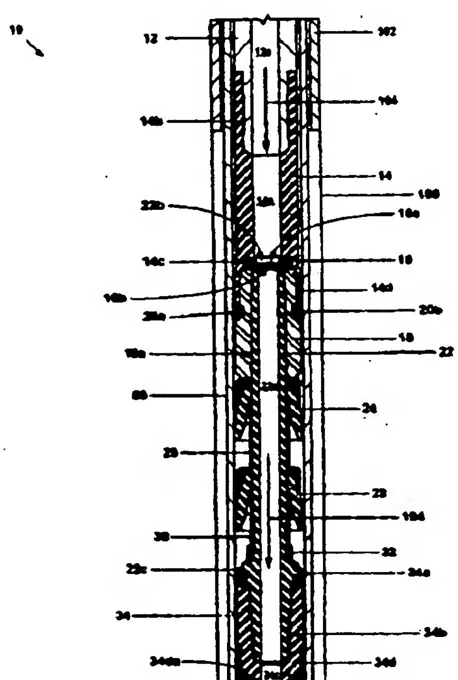
(54) Abstract Title: **Collapsible expansion cone**

(57) An apparatus (910) for radially expanding and plastically deforming an expandable tubular member (66) includes a collapsible expansion cone (44, 46).



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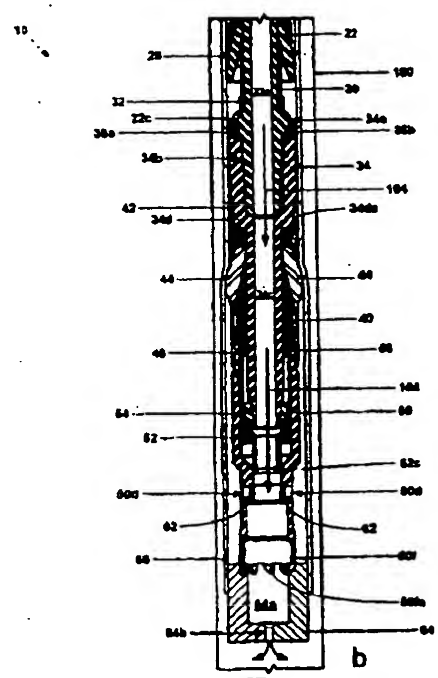

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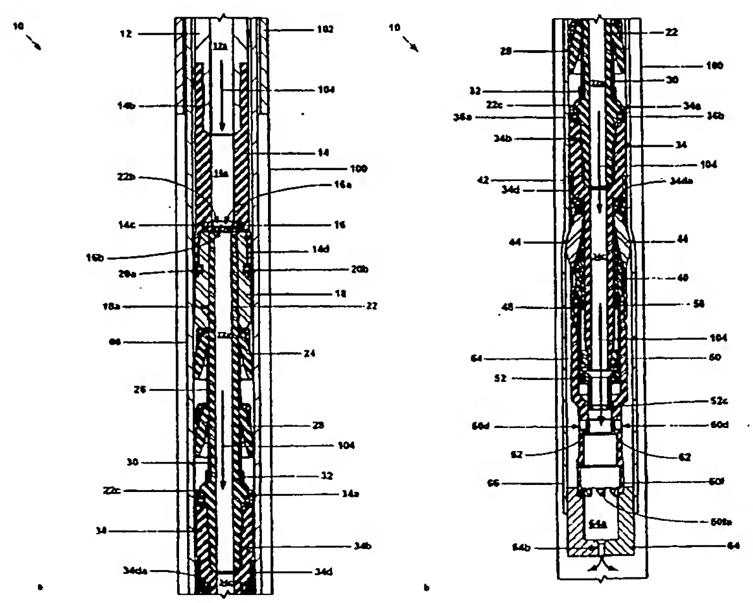
(54) Title: COLLAPSIBLE EXPANSION CONE



(57) Abstract: An apparatus for radially expanding and plastically deforming an expandable tubular member includes a collapsible expansion cone.

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COLLAPSIBLE EXPANSION CONE

Cross Reference To Related Applications

[001] The present application claims the benefit of the filing dates of (1) U.S. provisional patent application serial no. 60/387,961, attorney docket no 25791.108, filed on 6/12/2002, which is a continuation-in-part of U.S. provisional patent application serial no. 60/363,829, attorney docket no. 25791.95, filed on 3/12/2002, the disclosures of which are incorporated herein by reference.

[002] The present application is related to the following: (1) U.S. patent application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, (2) U.S. patent application serial no. 09/510,913, attorney docket no. 25791.7.02, filed on 2/23/2000, (3) U.S. patent application serial no. 09/502,350, attorney docket no. 25791.8.02, filed on 2/10/2000, (4) U.S. patent application serial no. 09/440,338, attorney docket no. 25791.9.02, filed on 11/15/1999, (5) U.S. patent application serial no. 09/523,460, attorney docket no. 25791.11.02, filed on 3/10/2000, (6) U.S. patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, (7) U.S. patent application serial no. 09/511,941, attorney docket no. 25791.16.02, filed on 2/24/2000, (8) U.S. patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, (9) U.S. patent application serial no. 09/559,122, attorney docket no. 25791.23.02, filed on 4/26/2000, (10) PCT patent application serial no. PCT/US00/18635, attorney docket no. 25791.25.02, filed on 7/9/2000, (11) U.S. provisional patent application serial no. 60/162,671, attorney docket no. 25791.27, filed on 11/1/1999, (12) U.S. provisional patent application serial no. 60/154,047, attorney docket no. 25791.29, filed on 9/16/1999, (13) U.S. provisional patent application serial no. 60/159,082, attorney docket no. 25791.34, filed on 10/12/1999, (14) U.S. provisional patent application serial no. 60/159,039, attorney docket no. 25791.36, filed on 10/12/1999, (15) U.S. provisional patent application serial no. 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999, (16) U.S. provisional patent application serial no. 60/212,359, attorney docket no. 25791.38, filed on 6/19/2000, (17) U.S. provisional patent application serial no. 60/165,228, attorney docket no. 25791.39, filed on 11/12/1999, (18) U.S. provisional patent application serial no. 60/221,443, attorney docket no. 25791.45, filed on 7/28/2000, (19) U.S. provisional patent application serial no. 60/221,645, attorney docket no. 25791.46, filed on 7/28/2000, (20) U.S. provisional patent application serial no. 60/233,638, attorney docket no. 25791.47, filed on 9/18/2000, (21) U.S. provisional patent application serial no. 60/237,334, attorney docket no. 25791.48, filed on 10/2/2000, (22) U.S. provisional patent application serial no. 60/270,007, attorney docket no. 25791.50, filed on 2/20/2001, (23) U.S. provisional patent application serial no. 60/262,434, attorney docket no. 25791.51, filed on 1/17/2001, (24) U.S. provisional patent application serial no. 60/259,486, attorney docket no. 25791.52, filed on 1/3/2001, (25) U.S. provisional patent application serial no. 60/303,740, attorney docket no. 25791.61, filed on 7/6/2001, (26) U.S. provisional patent application serial no. 60/313,453, attorney docket no. 25791.59, filed on 8/20/2001, (27) U.S. provisional patent application serial no. 60/317,985, attorney docket no. 25791.67, filed on 9/6/2001, (28) U.S. provisional patent application serial no. 60/3318,386, attorney docket no.

25791.67.02, filed on 9/10/2001, (29) U.S. utility patent application serial no. 09/969,922, attorney docket no. 25791.69, filed on 10/3/2001, (30) U.S. utility patent application serial no. 10/016,467, attorney docket no. 25791.70, filed on 12/10/2001; (31) U.S. provisional patent application serial no. 60/343,674, attorney docket no. 25791.68, filed on 12/27/2001; (32) U.S. provisional patent application serial no. 60/346,309, attorney docket no. 25791.92, filed on 1/7/2002; (33) U.S. provisional patent application serial no. 60/372,048, attorney docket no. 25791.93, filed on 4/12/2002; (34) U.S. provisional patent application serial no. 60/363,829, attorney docket no. 25791.95, filed on 3/13/2002; (35) U.S. provisional patent application serial no. 60/372,632, attorney docket no. 25791.101, filed on 4/15/2002; (36) U.S. provisional patent application serial no. 60/380,147, attorney docket no. 25791.104, filed on 5/6/2002; and (37) U.S. provisional patent application serial no. 60/387,486, attorney docket no. 25791.107, filed on 6/10/2002, the disclosures of which are incorporated herein by reference.

Background Of The Invention

[003] This invention relates generally to oil and gas exploration, and in particular to forming and repairing wellbore casings to facilitate oil and gas exploration.

[004] Conventionally, when a wellbore is created, a number of casings are installed in the borehole to prevent collapse of the borehole wall and to prevent undesired outflow of drilling fluid into the formation or inflow of fluid from the formation into the borehole. The borehole is drilled in intervals whereby a casing which is to be installed in a lower borehole interval is lowered through a previously installed casing of an upper borehole interval. As a consequence of this procedure the casing of the lower interval is of smaller diameter than the casing of the upper interval. Thus, the casings are in a nested arrangement with casing diameters decreasing in downward direction. Cement annuli are provided between the outer surfaces of the casings and the borehole wall to seal the casings from the borehole wall. As a consequence of this nested arrangement a relatively large borehole diameter is required at the upper part of the wellbore. Such a large borehole diameter involves increased costs due to heavy casing handling equipment, large drill bits and increased volumes of drilling fluid and drill cuttings. Moreover, increased drilling rig time is involved due to required cement pumping, cement hardening, required equipment changes due to large variations in hole diameters drilled in the course of the well, and the large volume of cuttings drilled and removed.

[005] The present invention is directed to overcoming one or more of the limitations of the existing procedures for forming new sections of casing in a wellbore.

Summary of the Invention

[006] According to one aspect of the present invention, an apparatus for radially expanding and plastically deforming an expandable tubular member is provided that includes an upper tubular support member defining a first passage, one or more cup seals coupled to the exterior surface of the upper tubular support member for sealing an interface between the upper tubular support member and the expandable tubular member, an upper cam assembly coupled to the upper tubular support member

comprising: a tubular base coupled to the upper tubular support member, and a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface, a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the tubular support member, a lower tubular support member defining a second passage fluidicly coupled to the first passage releasably coupled to the upper tubular support member, and a lower cam assembly coupled to the lower tubular support member comprising: a tubular base coupled to the lower tubular support member, and a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments, wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly, a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly, wherein the lower expansion cone segments interleave and overlap the upper expansion cone segments, and wherein the upper and lower expansion cone segments together define an arcuate spherical external surface for plastically deforming and radially expanding the expandable tubular member.

[007] According to another aspect of the present invention, a collapsible expansion cone assembly is provided that includes an upper tubular support member comprising an internal flange, an upper cam assembly coupled to the upper tubular support member comprising: a tubular base coupled to the upper support member, and a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface, a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the internal flange of the upper tubular support member, a lower tubular support member comprising an internal flange, one or more frangible couplings for releasably coupling the upper and lower tubular support members, a lower cam assembly coupled to the lower tubular support member comprising: a tubular base coupled to the lower tubular support member, and a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments, wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly, and a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the internal flange of the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly, wherein the lower expansion cone segments interleave and overlap the upper expansion cone segments, and wherein the upper and lower expansion cone segments together define an arcuate spherical external surface for plastically deforming and radially expanding the expandable tubular member.

[008] According to another aspect of the present invention, an apparatus for radially expanding and plastically deforming an expandable tubular member is provided that includes a tubular support member, a collapsible expansion cone coupled to the tubular support member, an expandable tubular member coupled to the collapsible expansion cone, means for displacing the collapsible expansion cone relative to the expandable tubular member, and means for collapsing the expansion cone.

[009] According to another aspect of the present invention, a collapsible expansion cone is provided that includes an upper cam assembly comprising: a tubular base, and a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface, a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly, a lower cam assembly comprising: a tubular base, and a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments, wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly, a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly, means for moving the upper cam assembly away from the lower expansion cone segments, and means for moving the lower cam assembly away from the upper expansion cone segments.

[0010] According to another aspect of the invention, an apparatus for radially expanding and plastically deforming an expandable tubular member is provided that includes a tubular support member, a collapsible expansion cone coupled to the tubular support member, an expandable tubular member coupled to the collapsible expansion cone, means for displacing the collapsible expansion cone relative to the expandable tubular member, and means for collapsing the expansion cone.

[0011] According to another aspect of the invention, a collapsible expansion cone is provided that includes an upper cam assembly comprising: a tubular base, and a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface, a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly, a lower cam assembly comprising: a tubular base, and a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments, wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly, a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly, means for moving the upper cam assembly away from the lower expansion cone segments, and means for moving the lower cam assembly away from the upper expansion cone segments.

[0012] According to another aspect of the invention, a method of radially expanding and plastically deforming an expandable tubular member is provided that includes supporting the expandable tubular member using a tubular support member and a collapsible expansion cone, injecting a fluidic material into the tubular support member, sensing the operating pressure of the injected fluidic material within a first interior portion of the tubular support member, displacing the collapsible expansion cone relative to the expandable tubular member when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the first interior portion of the tubular support member, sensing the operating pressure of the injected fluidic material within a second interior portion of the tubular support member, and collapsing the collapsible expansion cone when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the second interior portion of the tubular support member.

Brief Description of the Drawings

[0013] Fig. 1a is a fragmentary cross-sectional illustration of the placement of a portion of an exemplary embodiment of an apparatus for radially expanding and plastically deforming a tubular member that includes a collapsible expansion cone within a preexisting structure.

[0014] Fig. 1b is a fragmentary cross-sectional illustration of another portion of the apparatus of Fig. 1a.

[0015] Figs. 2a and 2b are fragmentary cross-sectional illustration of a portion of the apparatus of Figs. 1a and 1b.

[0016] Fig. 3 is a fragmentary cross-sectional illustration of a portion of the apparatus of Figs. 1a and 1b.

[0017] Fig. 3a is a fragmentary cross-sectional illustration of a portion of the apparatus of Fig 3.

[0018] Fig. 3b is a fragmentary cross-sectional illustration of a portion of the apparatus of Fig 3.

[0019] Fig. 4 is a fragmentary cross-sectional illustration of a portion of the apparatus of Figs. 1a and 1b.

[0020] Fig. 4a is a fragmentary cross-sectional illustration of a portion of the apparatus of Fig 4.

[0021] Fig. 5 is a fragmentary cross-sectional illustration of a portion of the apparatus of Figs. 1a and 1b.

[0022] Fig. 6 is a fragmentary cross-sectional illustration of a portion of the apparatus of Figs. 1a and 1b.

[0023] Figs. 7a-7e are fragmentary cross-sectional and perspective illustrations of the upper cam assembly of the apparatus of Figs. 1a and 1b.

[0024] Fig. 7f is a fragmentary cross-sectional illustration of the lower cam assembly of the apparatus of Figs. 1a and 1b.

[0025] Figs. 8a-8d are fragmentary cross-sectional and perspective illustrations of one of the upper cone segments of the apparatus of Figs. 1a and 1b.

[0026] Fig. 8e is a fragmentary cross-sectional illustration of one of the lower cone segments of the apparatus of Figs. 1a and 1b.

[0027] Fig. 9 is a side view of a portion of the apparatus of Figs. 1a and 1b.

[0028] Fig. 10a is a fragmentary cross sectional illustration of a portion of the apparatus of Figs. 1a and 1b during the radial expansion of the expandable tubular member.

[0029] Fig. 10b is a fragmentary cross sectional illustration of another portion of the apparatus of Fig. 10a.

[0030] Fig. 11a. is a fragmentary cross sectional illustration of a portion of the apparatus of Figs. 10a and 10b during the adjustment of the expansion cone to a collapsed position.

[0031] Fig. 11b is a fragmentary cross sectional illustration of another portion of the apparatus of Fig. 11a.

[0032] Fig. 12 is a fragmentary cross sectional illustration of a portion of the apparatus of Figs. 11a and 11b.

[0033] Fig. 13 is a fragmentary cross sectional illustration of a portion of the apparatus of Figs. 11a and 11b.

[0034] FIG. 14 is a fragmentary cross sectional illustration of a portion of the apparatus of Figs. 11a and 11b with the expansion cone in a half collapsed position.

[0035] FIG. 15 is a fragmentary cross sectional illustration of a portion of the apparatus of Figs. 11a and 11b with the expansion cone in a fully collapsed position.

[0036] Fig. 16 is a side view of a portion of the apparatus of Figs. 10a and 10b.

[0037] Fig. 17a. is a fragmentary cross sectional illustration of a portion of the apparatus of Figs. 11a and 11b after the removal of the apparatus from interior of the expandable tubular member.

[0038] Fig. 17b is a fragmentary cross sectional illustration of another portion of the apparatus of Fig. 17a.

[0039] Fig. 18 is a fragmentary cross sectional illustration of a cup seal.

[0040] Fig. 19a is a fragmentary cross sectional illustration of an alternative embodiment of a cup seal.

[0041] Fig. 19b is a fragmentary cross sectional illustration of an alternative embodiment of a cup seal.

[0042] Fig. 19c is a fragmentary cross sectional illustration of an alternative embodiment of a cup seal.

[0043] Fig. 19d is a fragmentary cross sectional illustration of an alternative embodiment of a cup seal.

[0044] Fig. 19e is a fragmentary cross sectional illustration of an alternative embodiment of a cup seal.

Detailed Description of the Illustrative Embodiments

[0045] Referring to Figs. 1a, 1b, 2a, 2b, 3, 3a, 4, 4a, 5, 6, 7a, 7b, 7c, 7d, 7e, 7f, 8a, 8b, 8c, 8d, 8e, and 9, an exemplary embodiment of an apparatus 10 for radially expanding and plastically deforming a tubular member includes a tubular support member 12 that defines a passage 12a. An end of the tubular support member 12 is coupled to an end of a safety collar 14 that defines a passage 14a, a recess 14b at one end for receiving the end of the tubular support member, and recesses 14c and 14d at another end.

[0046] A torque plate 16 is received within and is coupled to the recess 14c of the safety collar 14 that defines a passage 16a and a plurality of meshing teeth 16b at one end. An end of an upper mandrel collar 18 is received with and is coupled to the recess 14d of the safety collar 14 proximate and end of the torque plate 16 that defines a passage 18a. Torque pins 20a and 20b further couple the end of the upper mandrel collar 18 to the end of the safety collar 14.

[0047] An end of an upper mandrel 22 is received within and is coupled to the upper mandrel collar 18 that defines a passage 22a, a plurality of meshing teeth 22b that mate with and transmit torque to and from the meshing teeth 16b of the torque plate 16, and an external flange 22c at another end.

[0048] An upper cup seal or packer cup 24 mates with, receives and is coupled to the upper mandrel 22 proximate the end of the upper mandrel collar 18. An upper spacer sleeve 26 mates with, receives, and is coupled to the upper mandrel 22 proximate an end of the upper packer cup 24. A lower cup seal or packer cup 28 mates with, receives and is coupled to the upper mandrel 22 proximate an end of the upper spacer sleeve 26. In an exemplary embodiment, the packer cups 24 and 28 may be Guiberson™ packer cups. One embodiment of a Guiberson packer cup is discussed in detail below in reference to Fig. 18. Alternative embodiments of packer cups 24 and 28 are discussed below in reference to Figs. 19a-19e.

[0049] Turning back to Fig. 1, a lower spacer sleeve 30 mates with, receives, and is coupled to the upper mandrel 22 proximate an end of the lower packer cup 28 and the external flange 22c of the upper mandrel. A retaining sleeve 32 mates with, receives, and is coupled to an end of the lower spacer sleeve proximate the external flange 22c of the upper mandrel 22.

[0050] An end of a lower mandrel 34 defines a recess 34a that mates with, receives, and is coupled to the external flange 22c of the upper mandrel 22, a recess 34b that mates with, receives, and is coupled to the end of the upper mandrel, a passage 34c, and an external flange 34d including circumferentially spaced apart meshing teeth 34da on an end face of the external flange. Torque pins 36a and 36b further couple the recess 34a of the end of the lower mandrel 34 to the external flange 22c of the upper mandrel 22. During operation, the torque pins 36a and 36b transmit torque loads between the recess 34a of the end of the lower mandrel 34 and the external flange 22c of the upper mandrel 22.

[0051] An upper cam assembly 38 includes a tubular base 38a for receiving and mating with the lower mandrel 34 that includes an external flange 38aa, a plurality of circumferentially spaced apart meshing teeth 38b that extend from one end of the tubular base in the longitudinal and radial directions for engaging the meshing teeth 34da of the end face of the external flange 34d of the lower

mandrel, and a plurality of circumferentially spaced apart cam arms 38c that extend from the other end of the tubular base in the opposite longitudinal direction and mate with and receive the lower mandrel. During operation, the meshing teeth 34da of the end face of the external flange 34d of the lower mandrel 34 transmit torque loads to the meshing teeth 38b of the upper cam assembly 38.

Each of the cam arms 38c include an inner portion 38ca extending from the tubular base 38a that has arcuate cylindrical inner and outer surfaces, 38caa and 38cab, a tapered intermediate portion 38cb extending from the inner portion that has an arcuate cylindrical inner surface 38cba and an arcuate conical outer surface 38cbb, and an outer portion 38cc extending from the intermediate portion that has arcuate cylindrical inner and outer surfaces, 38cca and 38ccb. In an exemplary embodiment, the radius of curvatures of the arcuate outer cylindrical surfaces 38cab are greater than the radius of curvatures of the arcuate outer cylindrical surfaces 38ccb. In an exemplary embodiment, the radius of curvatures of the arcuate inner cylindrical surfaces, 38caa, 38cba, and 38cca are equal.

[0052] A lower cam assembly 40 includes a tubular base 40a for receiving and mating with the lower mandrel 34 that includes an external flange 40aa, a plurality of circumferentially spaced apart meshing teeth 40b that extend from one end of the tubular base in the longitudinal and radial directions, and a plurality of circumferentially spaced apart cam arms 40c that extend from the other end of the tubular base in the opposite longitudinal direction and mate with and receive the lower mandrel. Each of the cam arms 40c include an inner portion 40ca extending from the tubular base 40a that has arcuate cylindrical inner and outer surfaces, 40caa and 40cab, a tapered intermediate portion 40cb extending from the inner portion 40ca that has an arcuate cylindrical inner surface 40cba and an arcuate conical outer surface 40cbb, and an outer portion 40cc extending from the intermediate portion that has arcuate cylindrical inner and outer surfaces, 40cca and 40ccb. In an exemplary embodiment, the radius of curvatures of the arcuate outer cylindrical surfaces 40cab are greater than the radius of curvatures the arcuate outer cylindrical surfaces 40ccb. In an exemplary embodiment, the radius of curvatures of the arcuate inner cylindrical surfaces, 40caa, 40cba, and 40cca are equal. In an exemplary embodiment, the upper and lower cam assemblies, 38 and 40, are substantially identical. In an exemplary embodiment, the cam arms 38c of the upper cam assembly 38 interleave the cam arms 40c of the lower cam assembly 40. Furthermore, in an exemplary embodiment, the cam arms 38c of the upper cam assembly also overlap with the cam arms 40c of the lower cam assembly 40 in the longitudinal direction thereby permitting torque loads to be transmitted between the upper and lower cam assemblies.

[0053] An end of an upper retaining sleeve 42 receives and is threadably coupled to the external flange 34d of the lower mandrel 34 that defines a passage 42a for receiving and mating with the outer circumferential surfaces of the external flange 38aa and the meshing teeth 38b of the upper cam assembly 38, and an inner annular recess 42b, and includes an internal flange 42c for retaining the external flange 38aa of the upper cam assembly, and an internal flange 42d at one end of the upper retaining sleeve that includes a rounded interior end face. An o-ring seal 44 is received within the

annular recess 42b for sealing the interface between the upper retaining sleeve 42 and the external flange 34d of the lower mandrel 34. A disc shaped shim 43 is positioned within the upper retaining sleeve 42 between the opposing end faces of the internal flange 42c of the retaining sleeve and the meshing teeth 38b of the upper cam assembly 38.

[0054] A plurality of upper expansion cone segments 44 are interleaved among the cam arms 38c of the upper cam assembly 38. Each of the upper expansion cone segments 44 include inner portions 44a having arcuate cylindrical inner surfaces, 44aaa and 44aab, and an arcuate cylindrical outer surface 44ab, intermediate portions 44b extending from the interior portions that have an arcuate conical inner surface 44ba and arcuate cylindrical and spherical outer surfaces, 44bba and 44bbb, and outer portions 44c having arcuate cylindrical inner and outer surfaces, 44ca and 44cb. In an exemplary embodiment, the outer surfaces 44ab of the inner portions 44a of the upper expansion cone segments define hinge grooves 44aba that receive and are pivotally mounted upon the internal flange 42d of the upper retaining sleeve 42.

[0055] The arcuate inner cylindrical surfaces 44aaa mate with and receive the lower mandrel 34, the arcuate inner cylindrical surfaces 44aab mate with and receive the arcuate cylindrical outer surfaces 40ccb of the outer portions 40cc of the corresponding cam arms 40c of the lower cam assembly 40, and the arcuate inner conical surfaces 44ba mate with and receive the arcuate conical outer surfaces 40cbb of the intermediate portions 40cb of the corresponding cam arms of the lower cam assembly.

[0056] In an exemplary embodiment, the radius of curvature of the arcuate cylindrical inner surface 44aaa is less than the radius of curvature of the arcuate cylindrical inner surface 44aab. In an exemplary embodiment, the radius of curvature of the arcuate cylindrical inner surface 44ca is greater than the radius of curvature of the arcuate cylindrical surface 44aab. In an exemplary embodiment, the arcuate cylindrical inner surfaces, 44aaa and 44aab, are parallel. In an exemplary embodiment, the arcuate cylindrical outer surface 44ab is inclined relative to the arcuate cylindrical inner surface 44aaa. In an exemplary embodiment, the arcuate cylindrical outer surface 44bba is parallel to the arcuate cylindrical inner surfaces, 44aaa and 44aab. In an exemplary embodiment, the arcuate cylindrical outer surface 44cb is inclined relative to the arcuate cylindrical inner surface 44ca.

[0057] A plurality of lower expansion cone segments 46 are interleaved among, and overlap, the upper expansion cone segments 44 and the cam arms 38c of the lower cam assembly 38. In this manner, torque loads may be transmitted between the upper and lower expansion cone segments, 44 and 46. Each of the lower expansion cone segments 46 include inner portions 46a having arcuate cylindrical inner surfaces, 46aaa and 46aab, and an arcuate cylindrical outer surface 46ab, intermediate portions 46b extending from the interior portions that have an arcuate conical inner surface 46ba and arcuate cylindrical and spherical outer surfaces, 46bba and 46bbb, and outer portions 46c having arcuate cylindrical inner and outer surfaces, 46ca and 46cb. In an exemplary embodiment, the outer surfaces 46ab of the inner portions 46a of the upper expansion cone segments 46 define hinge grooves 46aba.

[0058] The arcuate inner cylindrical surfaces 46aaa mate with and receive the lower mandrel 34, the arcuate inner cylindrical surfaces 46aab mate with and receive the arcuate cylindrical outer surfaces 38ccb of the outer portions 38cc of the corresponding cam arms 38c of the upper cam assembly 38, and the arcuate inner conical surfaces 46ba mate with and receive the arcuate conical outer surfaces 38cbb of the intermediate portions 38cb of the corresponding cam arms of the lower cam assembly.

[0059] In an exemplary embodiment, the radius of curvature of the arcuate cylindrical inner surface 46aaa is less than the radius of curvature of the arcuate cylindrical inner surface 46aab. In an exemplary embodiment, the radius of curvature of the arcuate cylindrical inner surface 46ca is greater than the radius of curvature of the arcuate cylindrical surface 46aab. In an exemplary embodiment, the arcuate cylindrical inner surfaces, 46aaa and 46aab, are parallel. In an exemplary embodiment, the arcuate cylindrical outer surface 46ab is inclined relative to the arcuate cylindrical inner surface 46aaa. In an exemplary embodiment, the arcuate cylindrical outer surface 46bba is parallel to the arcuate cylindrical inner surfaces, 46aaa and 46aab. In an exemplary embodiment, the arcuate cylindrical outer surface 46cb is inclined relative to the arcuate cylindrical inner surface 46ca.

[0060] In an exemplary embodiment, the geometries of the upper and lower expansion cone segments 44 and 46 are substantially identical. In an exemplary embodiment, the upper expansion cone segments 44 are tapered in the longitudinal direction from the ends of the intermediate portions 44b to the ends of the outer portions 44c, and the lower expansion cone segments 46 are tapered in the longitudinal direction from the ends of the intermediate portions 46b to the ends of the outer portions 46c. In an exemplary embodiment, when the upper and lower expansion segments, 44 and 46, are positioned in a fully expanded position, the arcuate cylindrical outer surfaces, 44bba and 46cb, of the upper and lower expansion cone segments define a contiguous cylindrical surface, the arcuate spherical outer surfaces, 44bbb and 46bbb, of the upper and lower expansion cone segments define an contiguous arcuate spherical surface, and the arcuate cylindrical outer surfaces, 44cb and 46bba, of the upper and lower expansion cone segments define a contiguous cylindrical surface.

[0061] An end of a lower retaining sleeve 48 defines a passage 48a for receiving and mating with the outer circumferential surfaces of the external flange 40aa and the meshing teeth 40b of the lower cam assembly 40, and an inner annular recess 48b, and includes an internal flange 48c for retaining the external flange of the lower cam assembly, and an internal flange 48d at one end of the lower retaining sleeve that includes a rounded interior end face for mating with the hinge grooves 46 aba of the lower expansion cone segments 46 thereby pivotally coupling the lower expansion cone segments to the lower retaining sleeve. An o-ring seal 50 is received within the annular recess 48b. A disc shaped shim 49 is positioned within the lower retaining sleeve 48 between the opposing end faces of the internal flange 48c of the retaining sleeve and the external flange 40aa of the lower cam assembly 40.

[0062] In an exemplary embodiment, the arcuate cylindrical outer surfaces 44bba of the upper expansion cone segments 44 and the arcuate cylindrical outer surfaces 46cb of the lower expansion

cone segments 46 are aligned with the outer surface of the upper retaining sleeve 42. In an exemplary embodiment, the arcuate cylindrical outer surfaces 44cb of the upper expansion cone segments 44 and the arcuate cylindrical outer surfaces 46 bba of the lower expansion cone segments are aligned with the outer surface of the lower retaining sleeve 48.

[0063] An end of a float shoe adaptor 50 that includes a plurality of circumferentially spaced apart meshing teeth 50a for engaging the meshing teeth 40b of the lower cam assembly 40 is received within and threadably coupled to an end of the lower retaining sleeve 48 that defines a passage 50b at one end for receiving an end of the lower mandrel 34, a passage 50c having a reduced inside diameter at another end, a plurality of radial passages 50d at the other end, and includes an internal flange 50e, and a torsional coupling 50f at the other end that includes a plurality of torsional coupling members 50fa. During operation, the meshing teeth 40b of the lower cam assembly 40 transmit toque loads to and from the meshing teeth 50a of the float shoe adaptor.

[0064] An end of a retaining sleeve 52 abuts the end face of the tubular base 40a of the lower cam assembly 40 and is received within and mates with the passage 50b of the float shoe adaptor 50 that defines a passage 52a for receiving an end of the lower mandrel 34, a throat passage 52b including a ball valve seat 52c, and includes a flange 52d, and another end of the retaining sleeve, having a reduced outside diameter, is received within and mates with the passage 50c of the float shoe adaptor 50.

[0065] A stop nut 54 receives and is threadably coupled to the end of the lower mandrel 34 within the passage 52a of the retaining sleeve 52, and shear pins 56 releasably couple the stop nut 54 to the retaining sleeve 52. Locking dogs 58 are positioned within an end of the retaining sleeve 52 that receive and are releasably coupled to the lower mandrel 34, and a disc shaped adjustment shim 60 receives the lower mandrel 34 and is positioned within an end of the retaining sleeve 52 between the opposing ends of the tubular base 40a of the upper cam assembly 40 and the locking dogs 58. Burst discs 62 are releasably coupled to and positioned within the radial passages 50d of the float shoe adaptor 50.

[0066] An end of a float shoe 64 mates with and is releasably coupled to the torsional coupling members 50fa of the torsional coupling 50f of the float shoe adaptor 50 that defines a passage 64a and a valveable passage 64b. In this manner torsional loads may be transmitted between the float shoe adaptor 50 and the float shoe 64. An end of an expandable tubular member 66 that surrounds the tubular support member 12, the safety collar 14, the upper mandrel collar 18, the upper packer cup 24, the lower packer cup 28, the lower mandrel 34, the upper expansion cone segments 44, the lower expansion cone segments 46, and the float shoe adaptor 50, is coupled to and receives an end of the float shoe 64 and is movably coupled to and supported by the arcuate spherical external surfaces, 44bbb and 46bbb, of the upper and lower expansion cone segments, 44 and 46.

[0067] During operation, as illustrated in Figs. 1a and 1b, the apparatus 10 is at least partially positioned within a preexisting structure such as, for example, a borehole 100 that traverses a

subterranean formation that may include a preexisting wellbore casing 102. The borehole 100 may be oriented in any position, for example, from vertical to horizontal. A fluidic material 104 is then injected into the apparatus 10 through the passages 12a, 14a, 22a, 34c, 50c, 64a, and 64b into the annulus between the expandable tubular member 66 and the borehole 100. In an exemplary embodiment, the fluidic material 104 is a hardenable fluidic sealing material. In this manner, an annular sealing layer may be formed within the annulus between the expandable tubular member 66 and the borehole 100.

[0068] As illustrated in Figs. 10a and 10b, a ball 106 is then be positioned within and blocking the valveable passage 64b of the float shoe 64 by injecting a fluidic material 108 into the apparatus 10 through the passages 12a, 14a, 22a, 34c, and 50c. As a result, the increased operating pressure within the passage 50c bursts open the burst discs 62 positioned within the radial passages 50d of the float shoe adaptor 50. The continued injection of the fluidic material 108 thereby pressurizes the interior of the expandable tubular member 66 below the lower packer cup 28 thereby displacing the upper and lower expansion cone segments, 44 and 46, upwardly relative to the float shoe 64 and the expandable tubular member 66. As a result, the expandable tubular member 66 is plastically deformed and radially expanded. Thus, the burst discs 62 sense the operating pressure of the injected fluidic material 108 within the passage 50c and thereby control the initiation of the radial expansion and plastic deformation of the expandable tubular member 66.

[0069] In an exemplary embodiment, any leakage of the pressurized fluidic material 108 past the lower packer cup 28 is captured and sealed against further leakage by the upper packer cup 24. In this manner, the lower packer cup 28 provides the primary fluidic seal against the interior surface of the expandable tubular member 66, and the upper packer cup 24 provides a secondary, back-up, fluidic seal against the interior surface of the expandable tubular member. Furthermore, because the lower packer cup 28 and/or the upper packer cup 24 provide a fluid tight seal against the interior surface of the expandable tubular member 66, the upper and lower expansion cone segments, 44 and 46, are pulled upwardly through the expandable tubular member by the axial forces created by the packer cups.

[0070] In an exemplary embodiment, during the radial expansion process, the interface between the arcuate spherical external surfaces, 44bbb and 46bbb, of the upper and lower expansion cone segments, 44 and 46, and the interior surface of the expandable tubular member 66 is not fluid tight. As a result, the fluidic material 108 may provide lubrication to the entire extent of the interface between the cylindrical external surfaces, 44bba and 46cb, and the arcuate spherical external surfaces, 44bbb and 46bbb, of the upper and lower expansion cone segments, 44 and 46, and the interior surface of the expandable tubular member 66. Moreover, experimental test results have indicated the unexpected result that the required operating pressure of the fluidic material 108 for radial expansion of the expandable tubular member 66 is less when the interface between the cylindrical external surfaces, 44bba and 46cb, and the arcuate spherical external surfaces, 44bbb and 46bbb, of the upper

and lower expansion cone segments, 44 and 46, and the interior surface of the expandable tubular member 66 is not fluid tight. Furthermore, experimental test results have also demonstrated that the arcuate spherical external surface provided by the arcuate spherical external surfaces, 44bbb and 46bbb, of the upper and lower expansion cone segments, 44 and 46, provides radial expansion and plastic deformation of the expandable tubular member 66 using lower operating pressures versus an expansion cone having a conical outer surface.

[0071] In an exemplary embodiment, as illustrated in Figs. 11a, 11b, 12, 13, 14, 15, and 16, the upper and lower expansion cone segments, 44 and 46, may then be adjusted to a collapsed position by placing a ball 110 within the ball valve seat 52c of the throat passage 52b of the retaining sleeve 52. The continued injection of the fluidic material 108, after the placement of the ball 110 within the ball valve seat 52c, creates a differential pressure across the ball 110 thereby applying a downward longitudinal force onto the retaining sleeve 52 thereby shearing the shear pins 56. As a result, the retaining sleeve 52 is displaced in the downward longitudinal direction relative to the float shoe adaptor 50 thereby permitting the locking dogs 58 to be displaced outwardly in the radial direction. The outward radial displacement of the locking dogs 58 disengages the locking dogs from engagement with the lower mandrel 34. Thus, the shear pins 56 sense the operating pressure of the injected fluidic material 108 within the throat passage 52b and thereby controling the initiation of the collapsing of the upper and lower expansion cone segments, 44 and 46.

[0072] The continued injection of the fluidic material 108 continues to displace the retaining sleeve 52 in the downward longitudinal direction relative to the float shoe adaptor 50 until the external flange 52d of the retaining sleeve 52 impacts, and applies a downward longitudinal force to, the internal flange 50e of the float shoe adaptor. As a result, the float shoe adaptor 50 is then also displaced in the downward longitudinal direction relative to the lower mandrel 34. The downward longitudinal displacement of the float shoe adaptor 50 relative to the lower mandrel 34 causes the lower cam assembly 40, the lower expansion cone segments 46, and the lower retaining sleeve 48, which are rigidly attached to the float shoe adaptor, to also be displaced downwardly in the longitudinal direction relative to the lower mandrel 34, the upper cam assembly 38, and the upper expansion cone segments 44.

[0073] The downward longitudinal displacement of the lower cam assembly 40 relative to the upper expansion cone segments 44 causes the upper expansion cone segments to slide off of the conical external surfaces 40cbb of the lower cam assembly and thereby pivot inwardly in the radial direction about the internal flange 42d of the upper retaining sleeve 42. The downward longitudinal displacement of the lower expansion cone segments 46 relative to the upper cam assembly 38 causes the lower expansion cone segments 46 to slide off of the external conical surfaces 38cbb of the upper cam assembly and thereby pivot inwardly in the radial direction about the internal flange 48d of the lower retaining sleeve. As a result of the inward radial movement of the upper and lower expansion cone segments, 44 and 46, the arcuate external spherical surfaces, 44bbb and 46bbb, of the upper and

lower expansion cone segments, 44 and 46, no longer provide a substantially contiguous outer arcuate spherical surface.

[0074] The downward longitudinal movement of the retaining sleeve 42 and float shoe adaptor 50 relative to the lower mandrel 34 is stopped when the stop nut 54 impacts the locking dogs 58. At this point, as illustrated in Figs. 17a and 17b, the apparatus 10 may then be removed from the interior of the expandable tubular member 66.

[0075] Thus, the apparatus 10 may be removed from the expandable tubular member 66 prior to the complete radial expansion and plastic deformation of the expandable tubular member by controllably collapsing the upper and lower expansion cone segments, 44 and 46. As a result, the apparatus 10 provides the following benefits: (1) the apparatus is removable when expansion problems are encountered; (2) lower expansion forces are required because the portion of the expandable tubular member 66 between the packer cups, 24 and 28, and the expansion cone segments is exposed to the expansion fluid pressure; and (3) the expansion cone segments can be run down through the expandable tubular member, prior to radial expansion, and then the expansion cone segments can be expanded.

[0076] In several alternative embodiments, resilient members such as, for example, spring elements are coupled to the upper and lower expansion cone segments, 44 and 46, for resiliently biasing the expansion cone segments towards the expanded or collapsed position.

[0077] In several alternative embodiments, the placement of the upper and lower expansion cone segments, 44 and 46, in an expanded or collapsed position is reversible.

[0078] In several alternative embodiments, a small gap is provided between the upper and lower expansion cone segments, 44 and 46, when positioned in the expanded condition that varies from about .005 to .030 inches.

[0079] Turning back to Fig. 10a, as previously discussed, the lower packer cup 28 may be used to provide a primary fluidic seal against the interior surface of the expandable tubular member 66, and the upper packer cup 24 provides a secondary, back-up, fluidic seal against the interior surface of the expandable tubular member. Furthermore, because the lower packer cup 28 and/or the upper packer cup 24 provide a fluid tight seal against the interior surface of the expandable tubular member 66, when the region is pressurized, the upper and lower expansion cone segments, 44 and 46, are pulled upwardly through the expandable tubular member by the axial forces created by the packer cups.

[0080] The packer cups may be made from an elastomer, the type of which depends on design pressures, fluids and temperatures. In several embodiments, the packer cups 24 and 28 are coupled to annular reinforcing elements or supports which are bonded to the elastomer to hold the elastomer in place when running in and out of the casing and when pressurized. Conventionally, the support may be wire or a single insert, such as used in the "TP" cup from Halliburton of Duncan, Oklahoma. The support may be more complicated, for instance, it may comprise a bushing and a plurality of overlapping springs, such as used in the GW-HD cup from Guiberson Oil Tools of Alberta Canada.

[0081] Conventional packer cups are intended to remain stationary when pressurized. Any significant movement of a conventional packer cup when the cup has been pressurized may destroy the packer cup. Additionally, conventional packer cups may not be designed to hold the high pressures necessary for a casing expansion when moving through the casing. Pressure cycling and movement which occurs during casing expansion procedures may cause degradation of the elastomer and the bond between the elastomer and inserts. Eventually the elastomer disintegrates and the packer cup is unable to hold pressure. What is needed, therefore is a packer cup which can withstand the movement and pressures associated with the casing expansion procedure.

[0082] Turning now to Fig. 18, one side of a conventional cup seal or packer cup 70 is illustrated in detail. The opposing side is symmetrical about the center line of the packer cup. In the illustrated configuration, the packer cup 70 is shown located outside of the casing. Therefore, dashed lines represent the position of an expandable casing 71 relative to the packer cup 70. The packer cup 70 may be used as the upper packer cup 24 or lower packer cup 28 as described previously in reference to Figs. 1a and 10a. In several alternative embodiments, the central mandrel 72 has an external flange 74, which may provide longitudinal support for a retaining sleeve or adjusting ring 76. The adjusting ring 76 receives and is coupled to the central mandrel 72. A spacer sleeve 78 also receives and is coupled to the central mandrel 72 and is longitudinally positioned between the packer cup 70 and the adjusting ring 76. In several embodiments, the adjusting ring 76 threadingly engages the spacer sleeve 78 so that the longitudinal position of the spacer sleeve may be adjusted by rotating the spacer sleeve relative to the adjusting ring 76. In turn, the spacer sleeve 78 longitudinally positions and supports the packer cup 70.

[0083] In several exemplary embodiments, the packer cup 70 comprises one or more springs 80a and 80b which are bonded to and radially support an elastomeric sealing cup 82 to form a cup assembly 83. The elastomeric sealing cup 82 is generally conical in shape, having a substantially unrestricted lip portion 85 for sealingly engaging the interior ID of the expandable casing 71. Opposite the lip portion 85 is a base portion 87 which is supported by a conical bushing 84 positioned between the interior side of the cup assembly 83 and the central mandrel 72. A radial thimble 86 surrounds the base portion 87 of the cup assembly 83. The radial thimble 86 has an exterior diameter which is smaller than the interior diameter of the casing by a distance "A." In the embodiment illustrated in Fig. 18, the elastomeric sealing cup 82 is unsupported in a region "B" which may be generally defined as the region between a support, such as a radial thimble 86, and a point of contact "C" with the expandable casing 71.

[0084] Fig. 19a illustrates an alternative embodiment of a packer cup 90. In several exemplary embodiments, the packer cup 90 comprises one or more springs 92a and 92b which are bonded to and radially support an elastomeric sealing cup 94 to form a cup assembly 95. The elastomeric sealing cup 94 is generally conical in shape, having a substantially unrestricted lip portion 93 for sealingly engaging the interior ID of the expandable casing 71. Opposite the lip portion 93 is a base portion 97

which is supported by a conical bushing 96 positioned between the cup assembly and the central mandrel 72. The supported end of the cup assembly 95 is surrounded by a radial thimble 98. The radial thimble 98 has an exterior diameter which is slightly smaller than the interior diameter, causing the distance "A" to be reduced when compared to a conventional packer cup, such as illustrated in Fig. 18.

[0085] In the embodiment illustrated in Fig. 19a, the elastomeric sealing cup 94 is unsupported in a region "B" which may be generally defined as the region between a support, such as the radial thimble 98, and a point of contact "C" with the expandable casing 71. In this embodiment, the longitudinal length of the radial thimble 98 has been increased, which reduces the unsupported region "B" of the elastomeric sealing cup 94 when compared to a conventional packer cup.

[0086] Reducing the length "B" of the unsupported region and the distance "A" between the exterior diameter of the thimble 98 and the ID of the casing limits movement of the elastomeric sealing cup 94 when the packer cup is pressurized. This reduced movement improves the durability of the packer seal under greater pressures than conventional packer cups.

[0087] Fig. 19b illustrates an alternative embodiment of a packer cup 100. In several exemplary embodiments, the packer cup 100 comprises one or more springs 102a and 102b which are bonded to an elastomeric sealing cup 104 to form a cup assembly 105. The elastomeric sealing cup 104 is generally conical in shape, having a substantially unrestricted lip portion 103 for sealingly engaging the interior ID of the expandable casing 71. Opposite the lip portion 103 is a base portion 107 which is supported by a conical bushing 106 positioned between the elastoermic seal 104 and the central mandrel 72. A pliant backup member 108 is position between the elastomeric sealing cup 104 and a radial thimble 110. The backup member 108 may be made from any suitable pliant material, such as a fluoropolymer or fluoroelastomer (e.g., Teflon or PEEK). The use of the backup member 108 significantly reduces the unsupported region of the elastomeric sealing cup 104. Additionally, the backup member 108 easily extrudes when pressurized to expand into any gap between the outside diameter of the backup support and the ID of the casing providing a secondary seal.

[0088] The radial thimble 110 is similar to the radial thimble 98 (Fig. 19a) in that it has an exterior diameter which is slightly smaller than the interior diameter, causing the distance "A" to be reduced. Similarly, the longitudinal length of the radial thimble 110 has been increased which reduces the unsupported length of the elastomeric sealing cup. Reducing the unsupported region of the elastomeric sealing cup and the distance between the exterior diameter of the thimble 98 and the ID of the casing limits movement of the elastomeric sealing cup 94 when the packer cup is pressurized. This reduced movement improves the durability of the packer seal.

[0089] Fig. 19c illustrates an alternative embodiment of a packer cup 120. In several exemplary embodiments, the packer cup 120 comprises one or more springs 122a and 122b which are bonded to an elastomeric sealing cup 124 to form a cup assembly 125. The elastomeric sealing cup 124 is generally conical in shape, having a substantially unrestricted lip portion 123 for sealingly engaging

the interior ID of the expandable casing 71. Opposite the lip portion 123 is a base portion 127 which is supported by a conical bushing 126 positioned between the elastomeric sealing cup 124 and the central mandrel 72. A pliant backup member 128 is positioned between the elastomeric sealing cup 124 and a radial shoe 130. The backup member 128 may be made from any suitable pliant material, such as a fluoropolymer or fluoroelastomer (e.g., Teflon or PEEK). Additionally, the backup member 128 extrudes when pressurized to expand into a gap between the outside diameter of the backup member 128 and the ID of the casing. However, the use of the radial shoe 130 and the cross-sectional shape of the backup member 128 reduces the degree of extrusion when compared to packer cup 100 (Fig. 19b).

[0090] The radial shoe 130 may be made from steel or another harden material to provide support and protection for the pliant backup member 128. The pliant backup member 128 reduces the unsupported length of the elastomeric sealing cup 124 which limits the movement of the elastomeric sealing cup 124 when the packer cup is pressurized. This reduced movement improves the durability of the packer cup.

[0091] Fig. 19d illustrates an alternative embodiment of a packer cup 140. In several exemplary embodiments, the packer cup 140 comprises one or more springs 142a and 142b which are bonded to an elastomeric sealing cup 144 to form a cup assembly 145. The elastomeric sealing cup 144 is generally conical in shape, having a substantially unrestricted lip portion 143 for sealingly engaging the interior ID of the expandable casing 71. Opposite the lip portion 143 is a base portion 149 which is supported by a conical bushing 146 positioned between the elastomeric sealing cup 144 and the central mandrel 72. A support member 147 provides additional stiffness and support by surrounding the supported end of cup assembly 145. The support member 147 may be made of steel or another suitable material. The use of the support member 147 provides a stiff support for the elastomeric sealing cup 144 which reduces the movement of the elastomeric sealing cup 144. Similar to the packer cup 120 discussed in reference to Fig. 19c, a pliant backup member 148 is positioned between the support member 147 and a radial shoe 150. The backup member 148 extrudes when pressurized to expand into a gap between the outside diameter of the backup support and the ID of the casing. However, the use of the radial shoe 150 reduces the degree of extrusion when compared to packer cup 100 (Fig. 19b).

[0092] The radial shoe 150 may be made from steel or another harden material to provide support and protection for the pliant backup member 148. The use of a pliant backup member 148 also reduces the unsupported region of the elastomeric sealing cup 144 which limits the movement of the elastomeric sealing cup 144 when the packer cup is pressurized . This reduced movement improves the durability of the packer cup.

[0093] Fig. 19e illustrates an alternative embodiment of a packer cup 160. In several exemplary embodiments, the packer cup 160 comprises one or more springs 162a and 162b which are bonded to an elastomeric sealing cup 164 to form a cup assembly 165. The elastomeric sealing cup 164 is

generally conical in shape, having a substantially unrestricted lip portion 163 for sealingly engaging the interior ID of the expandable casing 71. Opposite the lip portion 163 is a base portion 167 which is supported by a conical bushing 166 positioned between the elastomeric sealing cup 164 and the central mandrel 72. The supported end of the cup assembly is also surrounded by a radial thimble 168.

[0094] In this embodiment, the elastomeric sealing cup 164 has additional elastomeric material molded proximate to the radial thimble 168 at a point "D". Because of the use of additional elastomeric material and a longer longitudinal length of the radial thimble 98, the unsupported region of the elastomeric sealing cup 164 is significantly reduced. Reducing the unsupported region of the elastomeric sealing cup 164 and the distance between the exterior diameter of the thimble 168 and the ID of the casing 71 limits movement of the elastomeric sealing cup 164 when the packer cup is pressurized. Additionally, the radial thimble 168 has an exterior diameter which is slightly smaller than the interior diameter, causing the gap between the radial thimble 168 and the ID of the casing 71 to be reduced. The reduced gap also limits movement of the elastomeric sealing cup 164. This reduced movement improves the durability of the packer seal.

[0095] An apparatus for radially expanding and plastically deforming an expandable tubular member has been described that includes an upper tubular support member defining a first passage, one or more cup seals coupled to the exterior surface of the upper tubular support member for sealing an interface between the upper tubular support member and the expandable tubular member, an upper cam assembly coupled to the upper tubular support member comprising: a tubular base coupled to the upper tubular support member, and a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface, a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the tubular support member, a lower tubular support member defining a second passage fluidicly coupled to the first passage releasably coupled to the upper tubular support member, a lower cam assembly coupled to the lower tubular support member comprising: a tubular base coupled to the lower tubular support member, and a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments, wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly, and a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly, wherein the lower expansion cone segments interleave and overlap the upper expansion cone segments, and wherein the upper and lower expansion cone segments together define an arcuate spherical external surface for plastically deforming and radially expanding the expandable tubular member. In an exemplary embodiment, the upper tubular support member includes: a safety collar, a

torque plate coupled to the safety collar including a plurality of circumferentially spaced apart meshing teeth at an end, an upper mandrel including a plurality of circumferentially spaced apart meshing teeth at one end for engaging the meshing teeth of the torque plate and an external flange at another end, and a lower mandrel coupled to the external flange of the upper mandrel including an external flange including a plurality of circumferentially spaced apart meshing teeth. In an exemplary embodiment, the tubular base of the upper cam assembly includes a plurality of circumferentially spaced apart meshing teeth for engaging the meshing teeth of the external flange of the lower mandrel. In an exemplary embodiment, the apparatus further includes a stop nut coupled to an end of the lower mandrel for limiting the movement of the lower tubular member relative to the lower mandrel. In an exemplary embodiment, the apparatus further includes locking dogs coupled to the lower mandrel. In an exemplary embodiment, the lower tubular support member includes: a float shoe adapter including a plurality of circumferentially spaced apart meshing teeth at one end, an internal flange, and a torsional coupling at another end, a lower retaining sleeve coupled to an end of the float shoe adapter including an internal flange for pivotally engaging the lower expansion cone segments, and a retaining sleeve received within the float shoe adapter releasably coupled to the upper tubular support member. In an exemplary embodiment, an end of the retaining sleeve abuts an end of the tubular base of the lower cam assembly. In an exemplary embodiment, the tubular base of the lower cam assembly includes a plurality of circumferentially spaced apart meshing teeth for engaging the meshing teeth of the float shoe adaptor. In an exemplary embodiment, the apparatus further includes a float shoe releasably coupled to the torsional coupling of the float shoe adaptor, and an expandable tubular member coupled to the float shoe and supported by and movably coupled to the upper and lower expansion cone segments. In an exemplary embodiment, the apparatus further includes: one or more shear pins coupled between the upper tubular support member and the lower tubular support member. In an exemplary embodiment, the apparatus further includes: a stop member coupled to the upper tubular support member for limiting movement of the upper tubular support member relative to the lower tubular support member. In an exemplary embodiment, the apparatus further includes: a float shoe releasably coupled to the lower tubular support member that defines a valveable passage, and an expandable tubular member coupled to the float shoe and supported by and movably coupled to the upper and lower expansion cone segments. In an exemplary embodiment, each upper expansion cone segment includes: an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the upper expansion cone segment to the upper tubular support member and arcuate cylindrical lower surfaces, an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface, and an outer portion defining arcuate cylindrical upper and lower surfaces, and wherein each lower expansion cone segment includes: an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the lower expansion cone segment to the lower tubular support member and arcuate cylindrical lower surfaces, an intermediate portion defining arcuate cylindrical and

spherical upper surfaces and an arcuate conical lower surface, and an outer portion defining arcuate cylindrical upper and lower surfaces. In an exemplary embodiment, each upper expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion; and wherein each lower expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion.

[0096] An apparatus for radially expanding and plastically deforming an expandable tubular member has also been described that includes a safety collar, a torque plate coupled to the safety collar including a plurality of circumferentially spaced apart meshing teeth at an end, an upper mandrel including a plurality of circumferentially spaced apart meshing teeth at one end for engaging the meshing teeth of the torque plate and an external flange at another end, a lower mandrel coupled to the external flange of the upper mandrel including an external flange including a plurality of circumferentially spaced apart meshing teeth, a stop nut coupled to an end of the lower mandrel, an upper retaining sleeve coupled to the lower mandrel including an internal flange, one or more cup seals coupled to the upper mandrel for sealing an interface between the upper mandrel and the expandable tubular member, an upper cam assembly coupled to the lower mandrel including: a tubular base including a plurality of circumferentially spaced apart meshing teeth for engaging the meshing teeth of the external flange of the lower mandrel, and a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface, a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the internal flange of the upper retaining sleeve, a float shoe adapter including a plurality of circumferentially spaced apart meshing teeth at one end, an internal flange, and a torsional coupling at another end, a lower retaining sleeve coupled to an end of the float shoe adapter including an internal flange, a retaining sleeve received within the float shoe adapter, one or more shear pins for releasably coupling the retaining sleeve to the stop nut, a lower cam assembly coupled to the float shoe adapter including: a tubular base including a plurality of circumferentially spaced apart meshing teeth for engaging the meshing teeth of the float shoe adapter, and a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments, wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly, a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the internal flange of the lower retaining sleeve and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly, a float shoe releasably coupled to the torsional coupling of the float shoe adaptor, and an expandable tubular member coupled to the float shoe and supported by and movably coupled to the upper and lower expansion cone segments, wherein the lower expansion cone segments interleave and overlap the upper expansion cone segments, wherein the upper and lower expansion cone segments together define an arcuate spherical

external surface for plastically deforming and radially expanding the expandable tubular member, wherein each upper expansion cone segment includes: an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the upper expansion cone segment to the upper tubular support member and arcuate cylindrical lower surfaces, an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface, and an outer portion defining arcuate cylindrical upper and lower surfaces, wherein each lower expansion cone segment includes: an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the lower expansion cone segment to the lower tubular support member and arcuate cylindrical lower surfaces, an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface, and an outer portion defining arcuate cylindrical upper and lower surfaces, wherein each upper expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion, and wherein each lower expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion.

[0097] A collapsible expansion cone assembly has also been described that includes an upper tubular support member including an internal flange, an upper cam assembly coupled to the upper tubular support member including: a tubular base coupled to the upper support member, and a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface, a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the internal flange of the upper tubular support member, a lower tubular support member including an internal flange, one or more frangible couplings for releasably coupling the upper and lower tubular support members, a lower cam assembly coupled to the lower tubular support member including: a tubular base coupled to the lower tubular support member, and a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments, wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly, and a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the internal flange of the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly, wherein the lower expansion cone segments interleave and overlap the upper expansion cone segments, and wherein the upper and lower expansion cone segments together define an arcuate spherical external surface for plastically deforming and radially expanding the expandable tubular member. In an exemplary embodiment, each upper expansion cone segment includes: an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the upper expansion cone segment to the upper tubular support member and arcuate cylindrical lower surfaces, an intermediate portion defining arcuate cylindrical and spherical upper

surfaces and an arcuate conical lower surface, and an outer portion defining arcuate cylindrical upper and lower surfaces, and wherein each lower expansion cone segment includes: an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the lower expansion cone segment to the lower tubular support member and arcuate cylindrical lower surfaces, an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface, and an outer portion defining arcuate cylindrical upper and lower surfaces. In an exemplary embodiment, each upper expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion, and wherein each lower expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion.

[0098] A collapsible expansion cone assembly has also been described that includes an upper tubular support member including an internal flange, an upper cam assembly coupled to the upper tubular support member including: a tubular base coupled to the upper support member, and a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface, a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the internal flange of the upper tubular support member, a lower tubular support member including an internal flange, one or more frangible couplings for releasably coupling the upper and lower tubular support members, a lower cam assembly coupled to the lower tubular support member including: a tubular base coupled to the lower tubular support member, and a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments, wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly, and a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the internal flange of the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly, wherein the lower expansion cone segments interleave and overlap the upper expansion cone segments, wherein the upper and lower expansion cone segments together define an arcuate spherical external surface for plastically deforming and radially expanding the expandable tubular member, wherein each upper expansion cone segment includes: an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the upper expansion cone segment to the upper tubular support member and arcuate cylindrical lower surfaces, an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface, and an outer portion defining arcuate cylindrical upper and lower surfaces, wherein each lower expansion cone segment includes: an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the lower expansion cone segment to the lower tubular support member and arcuate cylindrical lower surfaces, an intermediate portion defining

arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface, and an outer portion defining arcuate cylindrical upper and lower surfaces, wherein each upper expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion, and wherein each lower expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion.

[0099] An apparatus for radially expanding and plastically deforming an expandable tubular member has also been described that includes a tubular support member, a collapsible expansion cone coupled to the tubular support member, an expandable tubular member coupled to the collapsible expansion cone, means for displacing the collapsible expansion cone relative to the expandable tubular member, and means for collapsing the expansion cone. In an exemplary embodiment, the tubular support member includes an upper tubular support member including an internal flange and a lower tubular support member including an internal flange, wherein the expansion cone includes: an upper cam assembly coupled to the upper tubular support member including: a tubular base coupled to the upper support member, and a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface, a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the internal flange of the upper tubular support member, a lower cam assembly coupled to the lower tubular support member including: a tubular base coupled to the lower tubular support member, and a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments, wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly, and a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the internal flange of the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly; and wherein the apparatus further includes: means for releasably coupling the upper tubular support member to the lower tubular support member, and means for limiting movement of the upper tubular support member relative to the lower tubular support member. In an exemplary embodiment, the apparatus further includes: means for pivoting the upper expansion cone segments, and means for pivoting the lower expansion cone segments. In an exemplary embodiment, the apparatus further includes: means for pulling the collapsible expansion cone through the expandable tubular member.

[00100] A collapsible expansion cone has also been described that includes an upper cam assembly including: a tubular base, and a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface, a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly, a lower cam assembly including: a tubular base, and a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a

corresponding one of the upper expansion cone segments, wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly, a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly, means for moving the upper cam assembly away from the lower expansion cone segments, and means for moving the lower cam assembly away from the upper expansion cone segments. In an exemplary embodiment, the upper and lower expansion cone segments together define an arcuate spherical external surface. In an exemplary embodiment, each upper expansion cone segment includes: an inner portion defining an arcuate upper surface and arcuate cylindrical lower surfaces, an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface, and an outer portion defining arcuate cylindrical upper and lower surfaces, and wherein each lower expansion cone segment includes: an inner portion defining an arcuate cylindrical upper surface and arcuate cylindrical lower surfaces, an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface, and an outer portion defining arcuate cylindrical upper and lower surfaces. In an exemplary embodiment, each upper expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion, and each lower expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion.

[00101] Also disclosed is a packer cup apparatus comprising a central mandrel, a sealing cup comprising a substantially unrestricted lip for sealing engaging a tubular member, and a base portion for sealingly engaging the central mandrel, a protecting member positioned longitudinally along the central mandrel, and a pliant backup member positioned between the protecting member and the sealing cup, a conical bushing positioned partially between the sealing cup and the tubular support member for supporting the base portion of the sealing cup.

[00102] A method of radially expanding and plastically deforming an expandable tubular member has also been described that includes supporting the expandable tubular member using a tubular support member and a collapsible expansion cone, injecting a fluidic material into the tubular support member, sensing the operating pressure of the injected fluidic material within a first interior portion of the tubular support member, displacing the collapsible expansion cone relative to the expandable tubular member when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the first interior portion of the tubular support member, sensing the operating pressure of the injected fluidic material within a second interior portion of the tubular support member, and collapsing the collapsible expansion cone when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the second interior portion of the tubular support member. In an exemplary embodiment, the method further includes: pulling the collapsible expansion cone through the expandable tubular member when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the first interior portion

of the tubular support member. In an exemplary embodiment, pulling the collapsible expansion cone through the expandable tubular member includes: coupling one or more cup seals to the tubular support member above the collapsible expansion cone, pressuring the interior of the expandable tubular member below the cup seals, and pulling the collapsible expansion cone through the expandable tubular member using the cup seals. In an exemplary embodiment, the tubular support member includes an upper tubular support member and a lower tubular support member, and wherein collapsing the collapsible expansion cone includes displacing the upper tubular member relative to the lower tubular support member. In an exemplary embodiment, the collapsible expansion cone includes: an upper cam assembly including: a tubular base, and a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface, a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the upper tubular support member, a lower cam assembly including: a tubular base, and a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments, wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly, and a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly.

[00103] It is understood that variations may be made in the foregoing without departing from the scope of the invention. For example, the teachings of the present illustrative embodiments may be used to provide a wellbore casing, a pipeline, or a structural support. Furthermore, the elements and teachings of the various illustrative embodiments may be combined in whole or in part in some or all of the illustrative embodiments.

[00104] Although illustrative embodiments of the invention have been shown and described, a wide range of modification, changes and substitution is contemplated in the foregoing disclosure. In some instances, some features of the present invention may be employed without a corresponding use of the other features. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention.

Claims

What is claimed is:

1. An apparatus for radially expanding and plastically deforming an expandable tubular member, comprising:

an upper tubular support member defining a first passage;

one or more cup seals coupled to the exterior surface of the upper tubular support member for sealing an interface between the upper tubular support member and the expandable tubular member;

an upper cam assembly coupled to the upper tubular support member comprising:

a tubular base coupled to the upper tubular support member; and

a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface;

a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the tubular support member;

a lower tubular support member defining a second passage fluidicly coupled to the first passage releasably coupled to the upper tubular support member;

a lower cam assembly coupled to the lower tubular support member comprising:

a tubular base coupled to the lower tubular support member; and

a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments;

wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly; and

a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly;

wherein the lower expansion cone segments interleave and overlap the upper expansion cone segments; and

wherein the upper and lower expansion cone segments together define an arcuate spherical external surface for plastically deforming and radially expanding the expandable tubular member.

2. The apparatus of claim 1, wherein the upper tubular support member comprises:

a safety collar;

a torque plate coupled to the safety collar comprising a plurality of circumferentially spaced apart meshing teeth at an end;

an upper mandrel comprising a plurality of circumferentially spaced apart meshing teeth at one end for engaging the meshing teeth of the torque plate and an external flange at another end; and

a lower mandrel coupled to the external flange of the upper mandrel comprising an external flange comprising a plurality of circumferentially spaced apart meshing teeth.

3. The apparatus of claim 2, wherein the tubular base of the upper cam assembly comprises a plurality of circumferentially spaced apart meshing teeth for engaging the meshing teeth of the external flange of the lower mandrel.

4. The apparatus of claim 2, further comprising:

a stop nut coupled to an end of the lower mandrel for limiting the movement of the lower tubular member relative to thé lower mandrel.

5. The apparatus of claim 2, further comprising:

locking dogs coupled to the lower mandrel.

6. The apparatus of claim 1, wherein the lower tubular support member comprises:

a float shoe adapter comprising a plurality of circumferentially spaced apart meshing teeth at one end, an internal flange, and a torsional coupling at another end;

a lower retaining sleeve coupled to an end of the float shoe adapter comprising an internal flange for pivotally engaging the lower expansion cone segments; and

a retaining sleeve received within the float shoe adapter releasably coupled to the upper tubular support member.

7. The apparatus of claim 6, wherein an end of the retaining sleeve abuts an end of the tubular base of the lower cam assembly.

8. The apparatus of claim 6, wherein the tubular base of the lower cam assembly comprises a plurality of circumferentially spaced apart meshing teeth for engaging the meshing teeth of the float shoe adaptor.

9. The apparatus of claim 6, further comprising:

a float shoe releasably coupled to the torsional coupling of the float shoe adaptor; and

an expandable tubular member coupled to the float shoe and supported by and movably coupled to the upper and lower expansion cone segments.

10. The apparatus of claim 1, further comprising:

one or more shear pins coupled between the upper tubular support member and the lower tubular support member.

11. The apparatus of claim 1, further comprising:

a stop member coupled to the upper tubular support member for limiting movement of the upper tubular support member relative to the lower tubular support member.

12. The apparatus of claim 1, further comprising:

a float shoe releasably coupled to the lower tubular support member that defines a valveable passage; and

an expandable tubular member coupled to the float shoe and supported by and movably coupled to the upper and lower expansion cone segments.

13. The apparatus of claim 1, wherein each upper expansion cone segment comprises:

an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the upper expansion cone segment to the upper tubular support member and arcuate cylindrical lower surfaces;

an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and

an outer portion defining arcuate cylindrical upper and lower surfaces; and

wherein each lower expansion cone segment comprises:

an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the lower expansion cone segment to the lower tubular support member and arcuate cylindrical lower surfaces;

an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and

an outer portion defining arcuate cylindrical upper and lower surfaces.

14. The apparatus of claim 13, wherein each upper expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion; and wherein each lower expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion.

15. The apparatus of claim 1, wherein each of the one or more cup seals comprise:

a sealing cup comprising

a substantially unrestricted lip for sealing engaging the expandable tubular member, and

a base portion for sealingly engaging the tubular support member,

a protecting member positioned longitudinally along the tubular support member, and

a conical bushing positioned partially between the sealing cup and the tubular support member for supporting the base portion of the sealing cup.

16. The apparatus of claim 15 further comprising a pliant backup member positioned between the protecting member and the sealing cup.

17. The apparatus of claim 16 wherein the pliant backup member is made from a material selected from the group consisting of fluropolymer, fluoroelastomer, Telflon, or PEEK.

18. The apparatus of claim 15 further comprising a restraining member surrounding the base portion of the sealing cup for restraining the sealing cup.

19. The apparatus of claim 15 wherein the protecting member is a thimble surrounding the base portion of the sealing cup.

20. The apparatus of claim 19 wherein the sealing cup further comprises an unsupported portion between the thimble and a point of engagement with the expandable tubular member, and a means for reducing the unsupported portion of the sealing cup.

21. An apparatus for radially expanding and plastically deforming an expandable tubular member, comprising:

a safety collar;

a torque plate coupled to the safety collar comprising a plurality of circumferentially spaced apart meshing teeth at an end;

an upper mandrel comprising a plurality of circumferentially spaced apart meshing teeth at one end for engaging the meshing teeth of the torque plate and an external flange at another end;

a lower mandrel coupled to the external flange of the upper mandrel comprising an external flange comprising a plurality of circumferentially spaced apart meshing teeth;

a stop nut coupled to an end of the lower mandrel;

an upper retaining sleeve coupled to the lower mandrel comprising an internal flange;

one or more cup seals coupled to the upper mandrel for sealing an interface between the upper mandrel and the expandable tubular member;

an upper cam assembly coupled to the lower mandrel comprising:

a tubular base comprising a plurality of circumferentially spaced apart meshing teeth for engaging the meshing teeth of the external flange of the lower mandrel; and

a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface;

a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the internal flange of the upper retaining sleeve;

a float shoe adapter comprising a plurality of circumferentially spaced apart meshing teeth at one end, an internal flange, and a torsional coupling at another end;

a lower retaining sleeve coupled to an end of the float shoe adapter comprising an internal flange;

a retaining sleeve received within the float shoe adapter;

one or more shear pins for releasably coupling the retaining sleeve to the stop nut;

a lower cam assembly coupled to the float shoe adapter comprising:

a tubular base comprising a plurality of circumferentially spaced apart meshing teeth for engaging the meshing teeth of the float shoe adapter; and

a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments;

wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly;

a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the internal flange of the lower retaining sleeve and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly;

a float shoe releasably coupled to the torsional coupling of the float shoe adaptor; and

an expandable tubular member coupled to the float shoe and supported by and movably coupled to the upper and lower expansion cone segments;

wherein the lower expansion cone segments interleave and overlap the upper expansion cone segments;

wherein the upper and lower expansion cone segments together define an arcuate spherical external surface for plastically deforming and radially expanding the expandable tubular member;

wherein each upper expansion cone segment comprises:

an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the upper expansion cone segment to the upper tubular support member and arcuate cylindrical lower surfaces;

an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and

an outer portion defining arcuate cylindrical upper and lower surfaces;

wherein each lower expansion cone segment comprises:

an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the lower expansion cone segment to the lower tubular support member and arcuate cylindrical lower surfaces;

an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and

an outer portion defining arcuate cylindrical upper and lower surfaces;

wherein each upper expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion; and

wherein each lower expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion.

22. A collapsible expansion cone assembly comprising:

an upper tubular support member comprising an internal flange;

an upper cam assembly coupled to the upper tubular support member comprising:

a tubular base coupled to the upper support member; and

a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface;

a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the internal flange of the upper tubular support member;

a lower tubular support member comprising an internal flange;

one or more frangible couplings for releasably coupling the upper and lower tubular support members;

a lower cam assembly coupled to the lower tubular support member comprising:

a tubular base coupled to the lower tubular support member; and

a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments;

wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly; and

a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the internal flange of the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly;

wherein the lower expansion cone segments interleave and overlap the upper expansion cone segments; and

wherein the upper and lower expansion cone segments together define an arcuate spherical external surface for plastically deforming and radially expanding the expandable tubular member.

23. The assembly of claim 22, wherein each upper expansion cone segment comprises:

an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the upper expansion cone segment to the upper tubular support member and arcuate cylindrical lower surfaces;

an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and

an outer portion defining arcuate cylindrical upper and lower surfaces; and

wherein each lower expansion cone segment comprises:

an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the lower expansion cone segment to the lower tubular support member and arcuate cylindrical lower surfaces;

an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and

an outer portion defining arcuate cylindrical upper and lower surfaces.

24. The assembly of claim 22, wherein each upper expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion; and

wherein each lower expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion.

25. A collapsible expansion cone assembly, comprising:

an upper tubular support member comprising an internal flange;

an upper cam assembly coupled to the upper tubular support member comprising:

a tubular base coupled to the upper support member; and

a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface;

a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the internal flange of the upper tubular support member;

a lower tubular support member comprising an internal flange;

one or more frangible couplings for releasably coupling the upper and lower tubular support members;

a lower cam assembly coupled to the lower tubular support member comprising:

a tubular base coupled to the lower tubular support member; and

a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments;

wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly; and

a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the internal flange of the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly;

wherein the lower expansion cone segments interleave and overlap the upper expansion cone segments;

wherein the upper and lower expansion cone segments together define an arcuate spherical external surface for plastically deforming and radially expanding the expandable tubular member;

wherein each upper expansion cone segment comprises:

an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the upper expansion cone segment to the upper tubular support member and arcuate cylindrical lower surfaces;

an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and

an outer portion defining arcuate cylindrical upper and lower surfaces;

wherein each lower expansion cone segment comprises:

an inner portion defining an arcuate cylindrical upper surface including a hinge groove for pivotally coupling the lower expansion cone segment to the lower tubular support member and arcuate cylindrical lower surfaces;

an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and

an outer portion defining arcuate cylindrical upper and lower surfaces;

wherein each upper expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion; and

wherein each lower expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion.

26. An apparatus for radially expanding and plastically deforming an expandable tubular member, comprising:

a tubular support member;

a collapsible expansion cone coupled to the tubular support member;

an expandable tubular member coupled to the collapsible expansion cone;

means for displacing the collapsible expansion cone relative to the expandable tubular member; and

means for collapsing the expansion cone.

27. The apparatus of claim 26, wherein the tubular support member comprises an upper tubular support member comprising an internal flange and a lower tubular support member comprising an internal flange; wherein the expansion cone comprises:

an upper cam assembly coupled to the upper tubular support member comprising:

a tubular base coupled to the upper support member; and

a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface;

a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the internal flange of the upper tubular support member;

a lower cam assembly coupled to the lower tubular support member comprising:

a tubular base coupled to the lower tubular support member; and

a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments;

wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly; and

a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the internal flange

of the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly; and wherein the apparatus further comprises:

means for releasably coupling the upper tubular support member to the lower tubular support member; and

means for limiting movement of the upper tubular support member relative to the lower tubular support member.

28. The apparatus of claim 26, further comprising:

means for pivoting the upper expansion cone segments; and

means for pivoting the lower expansion cone segments..

29. The apparatus of claim 26, further comprising:

means for pulling the collapsible expansion cone through the expandable tubular member.

30. A collapsible expansion cone, comprising:

an upper cam assembly comprising:

a tubular base; and

a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface;

a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly;

a lower cam assembly comprising:

a tubular base; and

a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments;

wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly;

a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly;

means for moving the upper cam assembly away from the lower expansion cone segments; and

means for moving the lower cam assembly away from the upper expansion cone segments.

31. The apparatus of claim 30, wherein the upper and lower expansion cone segments together define an arcuate spherical external surface.

32. The apparatus of claim 30, wherein each upper expansion cone segment comprises:
an inner portion defining an arcuate cylindrical upper surface and arcuate cylindrical lower surfaces;
an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and
an outer portion defining arcuate cylindrical upper and lower surfaces; and
wherein each lower expansion cone segment comprises:
an inner portion defining an arcuate cylindrical upper surface and arcuate cylindrical lower surfaces;
an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and
an outer portion defining arcuate cylindrical upper and lower surfaces.

33. The apparatus of claim 30, wherein each upper expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion; and
wherein each lower expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion.

34. A packer cup apparatus comprising:
a central mandrel,
a sealing cup comprising
a substantially unrestricted lip for sealing engaging a tubular member, and
a base portion for sealingly engaging the central mandrel,
a protecting member positioned longitudinally along the central mandrel,
a pliant backup member positioned between the protecting member and the sealing cup,
a conical bushing positioned partially between the sealing cup and the central mandrel for supporting the base portion of the sealing cup.

35. The apparatus of claim 34 wherein the pliant backup member is made from a material selected from the group consisting of fluropolymer, fluoroelastomer, Telflon, or PEEK.

36. The apparatus of claim 34 further comprising a restraining member surrounding the base portion of the sealing cup for restraining the sealing cup.

37. The apparatus of claim 34 wherein the protecting member is a thimble surrounding the base portion of the sealing cup.

38. The apparatus of claim 37 wherein the sealing cup further comprises an unsupported portion between the thimble and a point of engagement with the expandable tubular member, and a means for reducing the unsupported portion of the sealing cup.

39. A method of radially expanding and plastically deforming an expandable tubular member, comprising:

supporting the expandable tubular member using a tubular support member and a collapsible expansion cone;

injecting a fluidic material into the tubular support member;

sensing the operating pressure of the injected fluidic material within a first interior portion of the tubular support member;

displacing the collapsible expansion cone relative to the expandable tubular member when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the first interior portion of the tubular support member;

sensing the operating pressure of the injected fluidic material within a second interior portion of the tubular support member; and

collapsing the collapsible expansion cone when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the second interior portion of the tubular support member.

40. The method of claim 34, further comprising:

pulling the collapsible expansion cone through the expandable tubular member when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the first interior portion of the tubular support member.

41. The method of claim 40, wherein pulling the collapsible expansion cone through the expandable tubular member comprises:

coupling one or more cup seals to the tubular support member above the collapsible expansion cone;

pressuring the interior of the expandable tubular member below the cup seals; and

pulling the collapsible expansion cone through the expandable tubular member using the cup seals.

42. The method of claim 34, wherein the tubular support member comprises an upper tubular support member and a lower tubular support member; and wherein collapsing the collapsible expansion cone comprises displacing the upper tubular member relative to the lower tubular support member.

43. The method of claim 42, wherein the collapsible expansion cone comprises:
an upper cam assembly comprising:
a tubular base; and
a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface;
a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the upper tubular support member;
a lower cam assembly comprising:
a tubular base; and
a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments;
wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly; and
a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly.

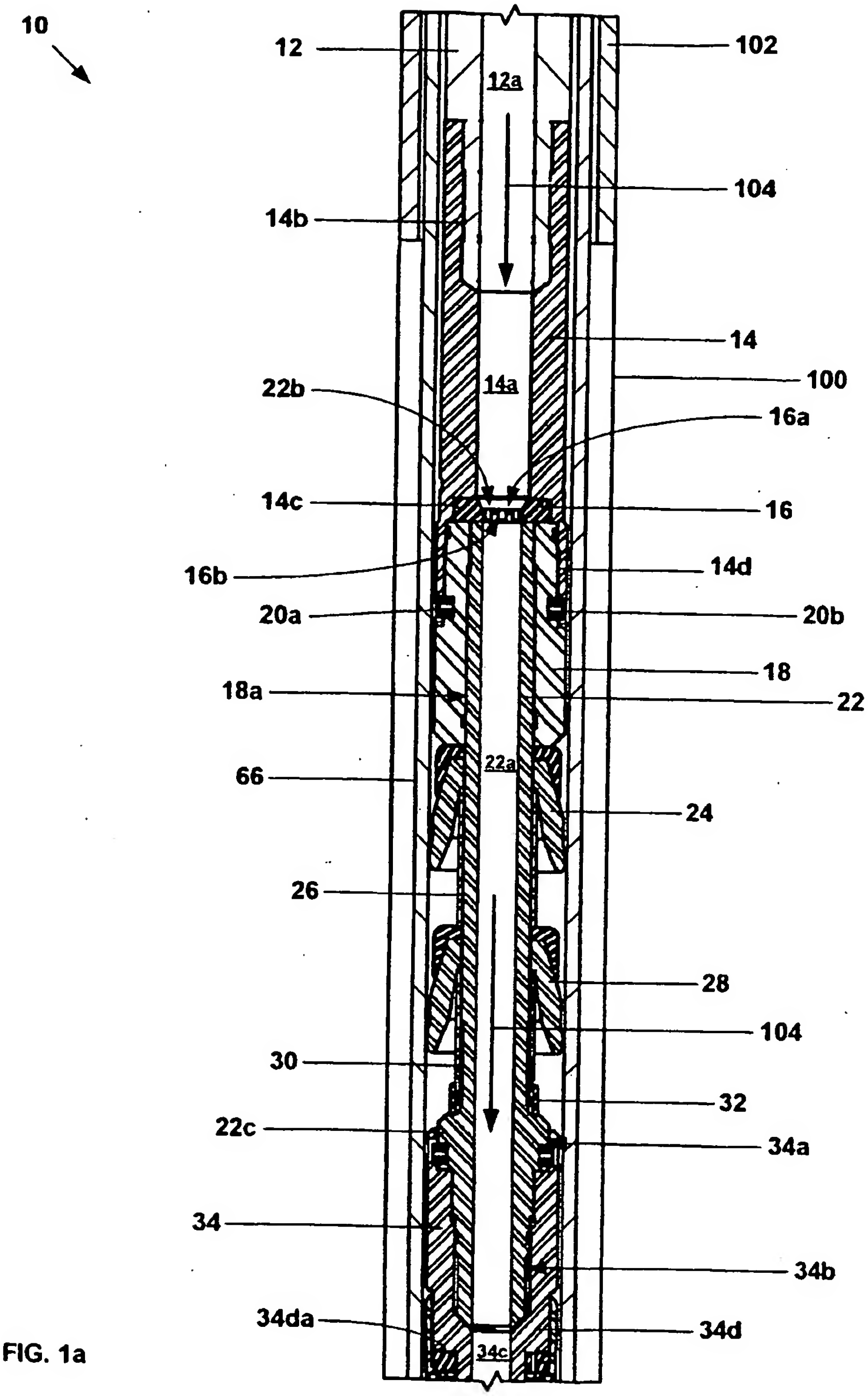

10
12
12a
102
104
14b
14
14a
100
22b
16a
14c
16
16b
14d
20a
20b
18
18a
22
22a
66
24
26
28
104
30
32
22c
34a
34
34b
34da
34d
34c

FIG. 1a

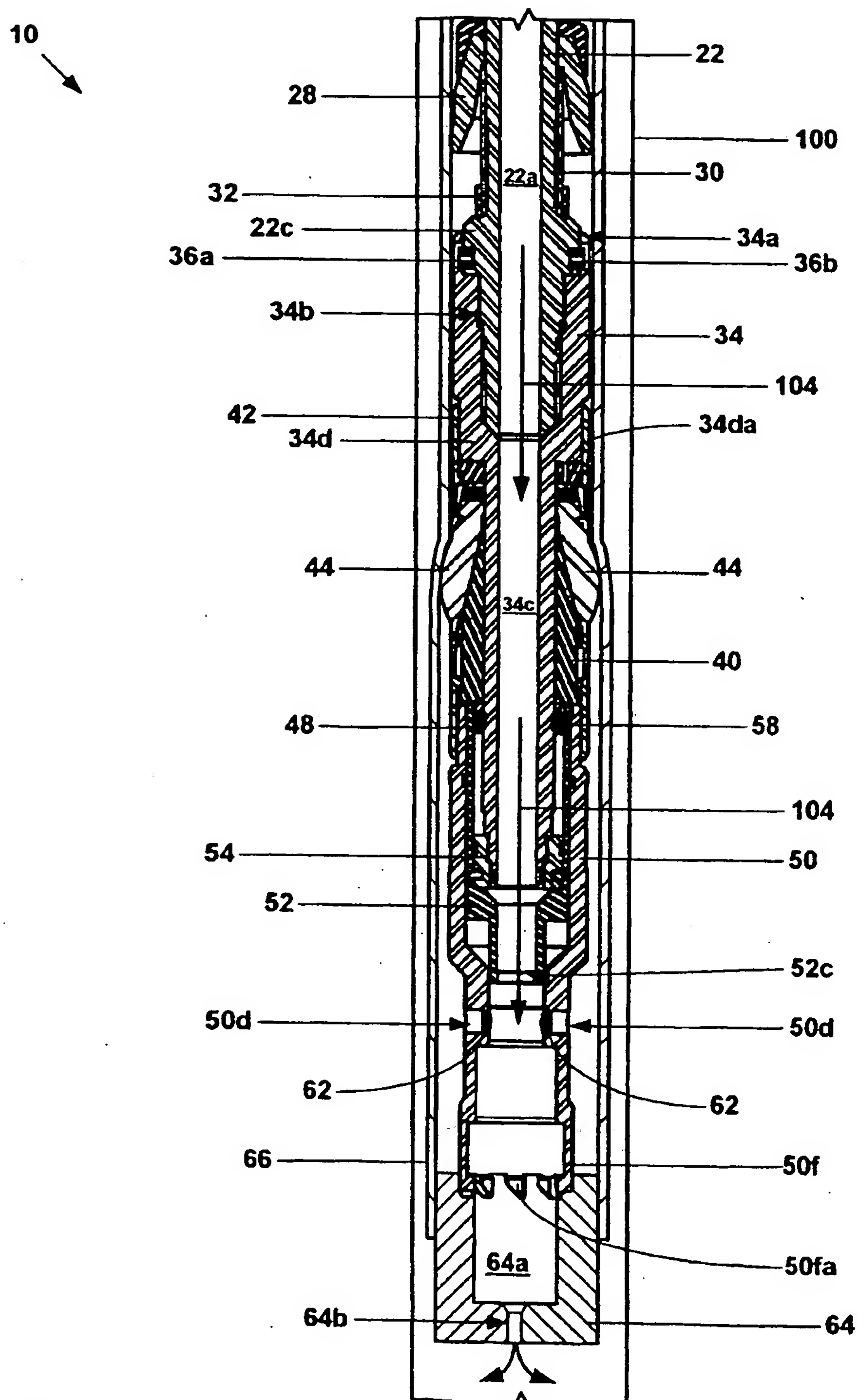

10
22
28
100
22a
30
32
22c
34a
36a
36b
34b
34
104
42
34da
34d
44
44
34c
40
48
58
104
54
50
52
52c
50d
50d
62
62
66
50f
50fa
64a
64b
64

FIG. 1b

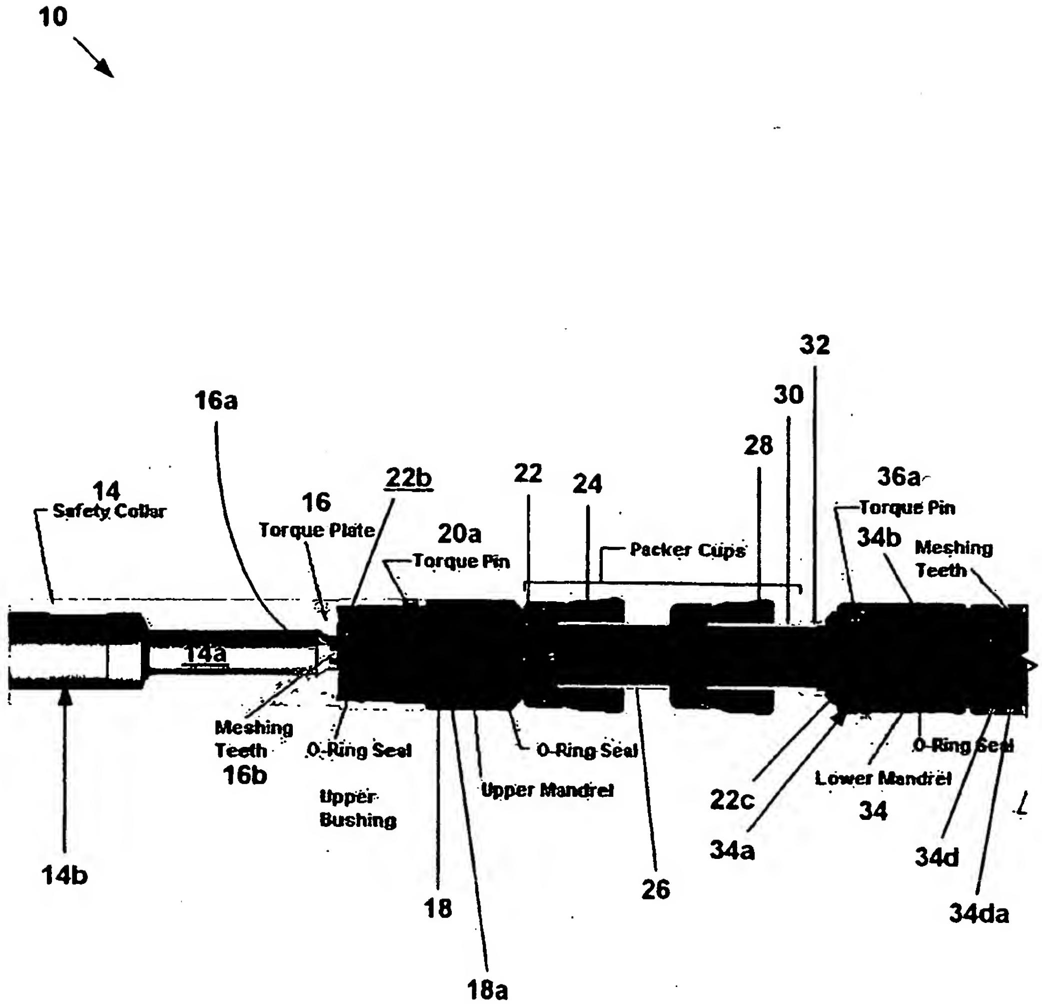

10
32
30
28
16a
22b
22
24
36a
14
Safety Collar
16
Torque Plate
20a
Torque Pin
Packer Cups
Torque Pin
34b
Meshing Teeth
14a
Meshing Teeth
16b
O-Ring Seal
Upper Bushing
O-Ring Seal
Upper Mandrel
22c
34a
Lower Mandrel
34
O-Ring Seal
34d
34da
14b
18
18a
26

FIG. 2a

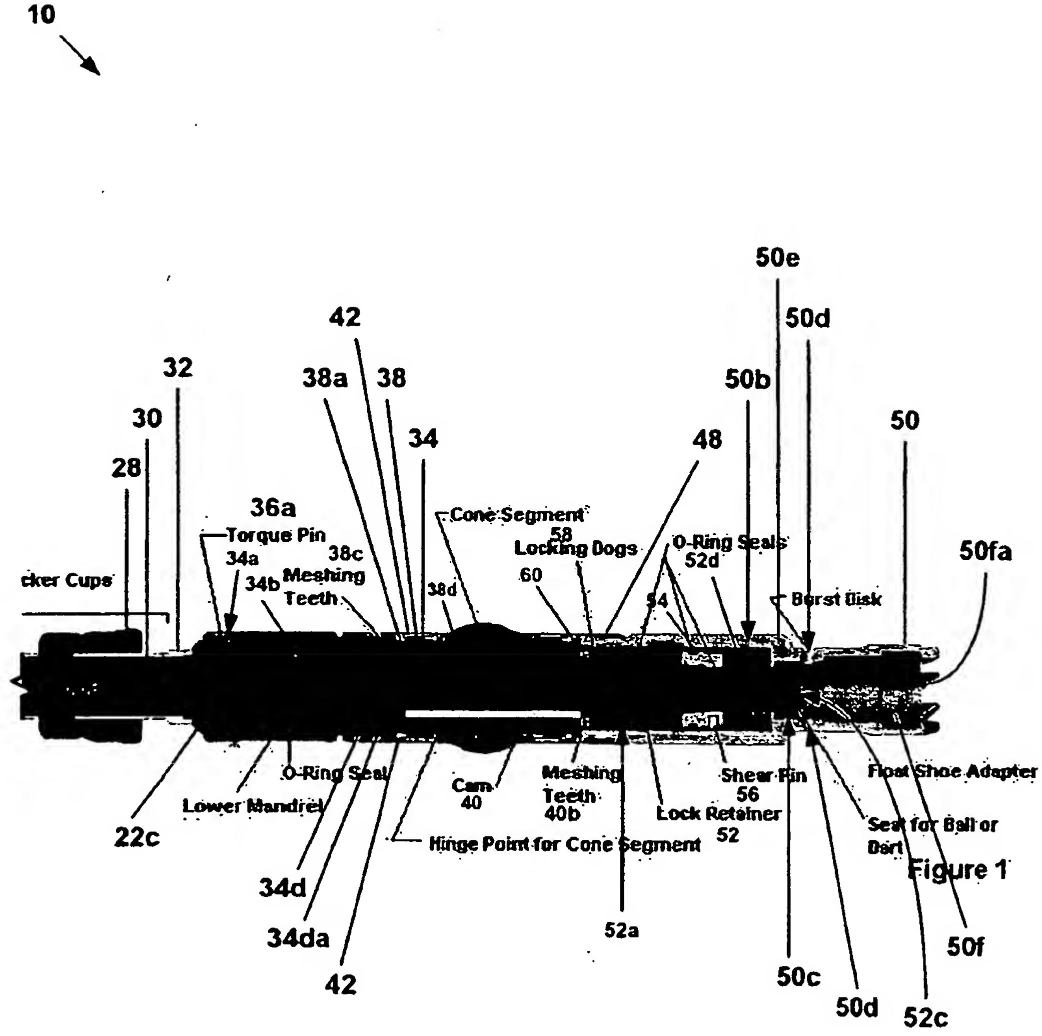

10
50e
42
50d
32
38a
38
50b
30
34
48
50
28
36a
Cone Segment
58
Torque Pin
34a
38c
Locking Dogs
O-Ring Seals
52d
50fa
cker Cups
34b
Meshing
Teeth
38d
60
54
Burst Disk
22c
Lower Mandrel
O-Ring Seal
Cam
40
Meshing
Teeth
40b
Shear Pin
56
Lock Retainer
52
Float Shoe Adapter
Seat for Ball or
Dart
Hinge Point for Cone Segment
Figure 1
34d
34da
42
52a
50c
50d
52c
50f

FIG. 2b

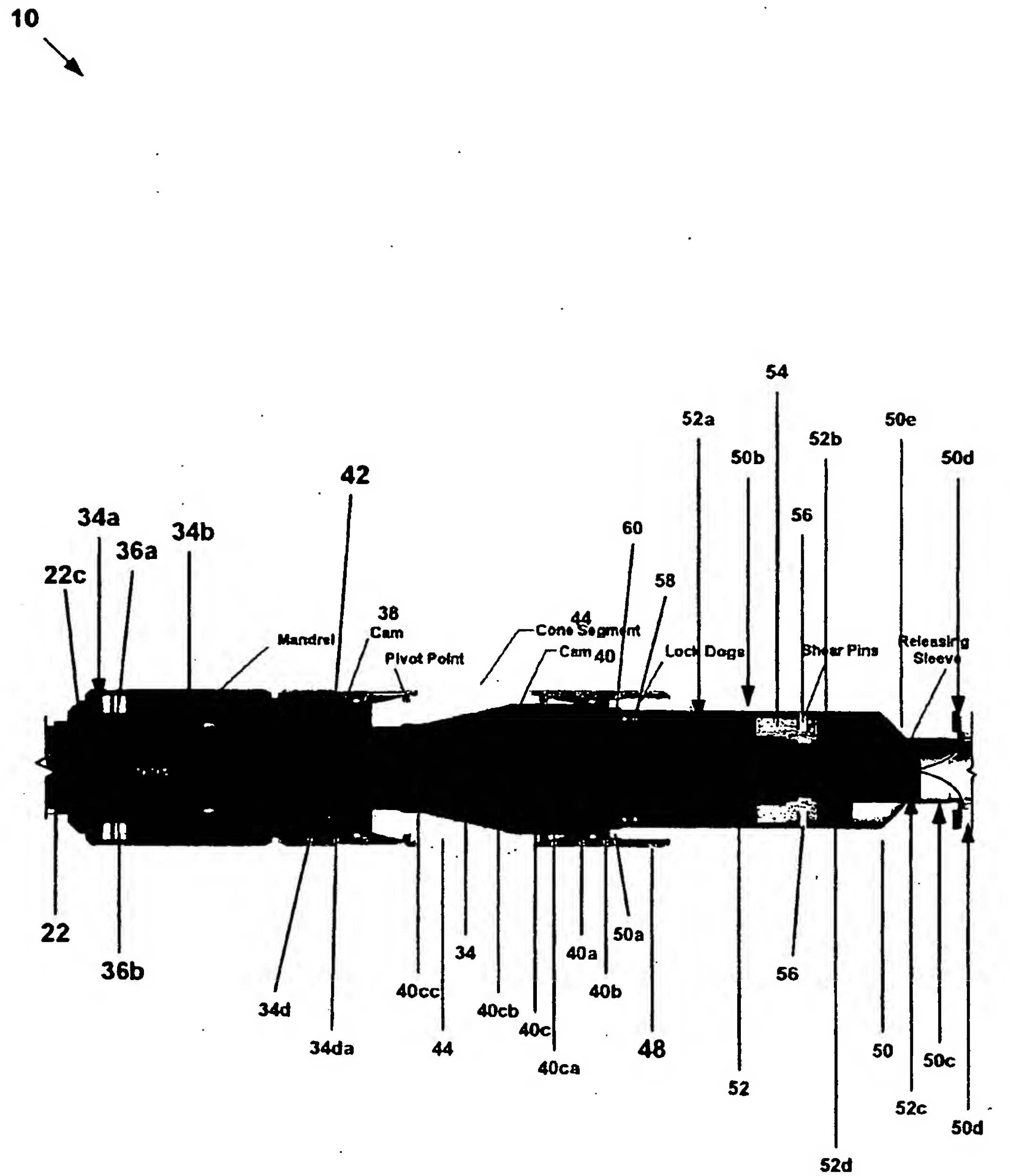

10
54
52a
50e
52b
50b
50d
42
34a
34b
36a
22c
60
56
58
38
Mandrel
Cam
Pivot Point
44
Cone Segment
Cam
40
Lock Dogs
Shear Pins
Releasing Sleeve
22
36b
34d
34da
34
40cc
44
40cb
40c
40ca
40a
40b
50a
48
56
52
50
52c
50c
50d
52d

FIG. 3

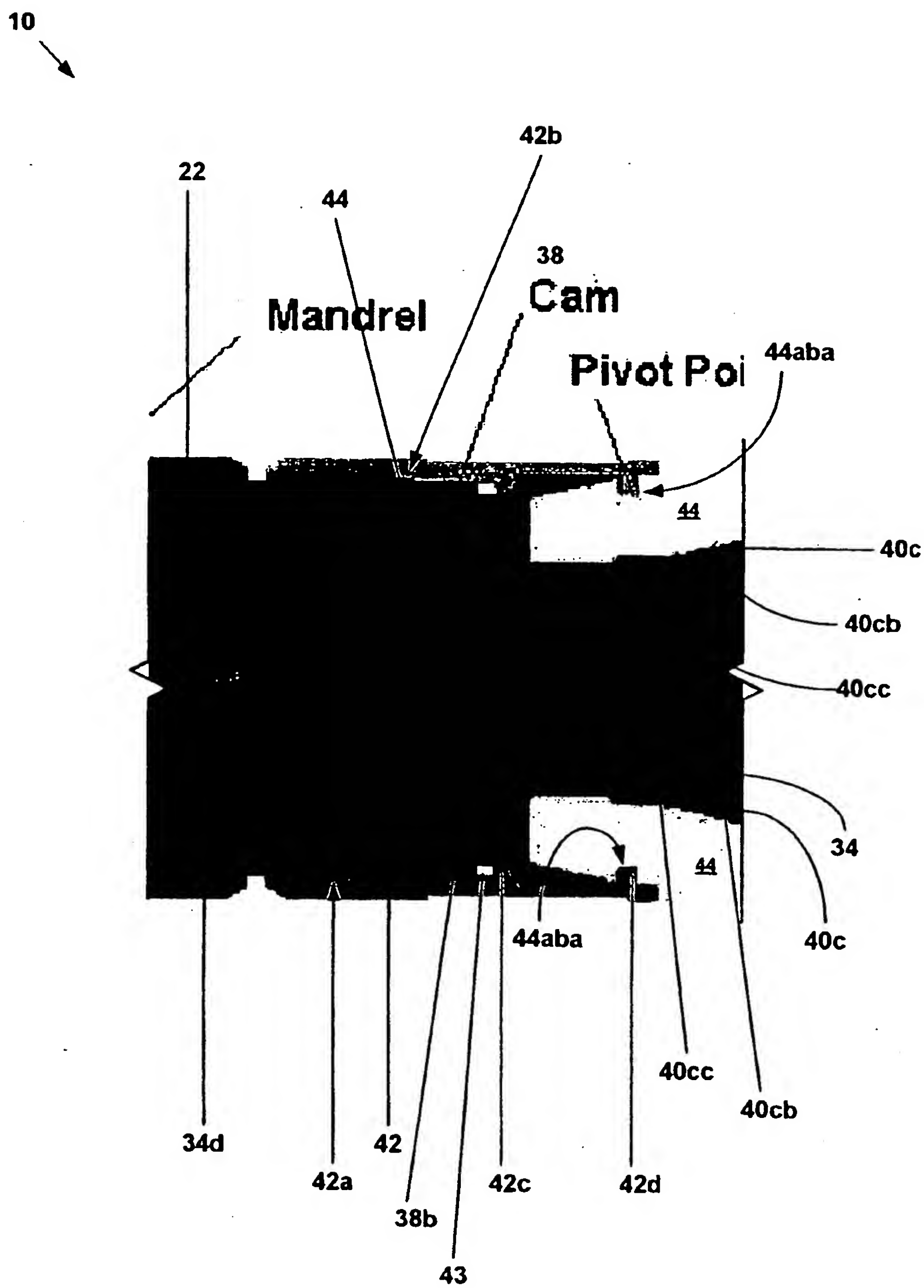

10
42b
22
44
38
Cam
Mandrel
Pivot Poi
44aba
44
40c
40cb
40cc
34
44
44aba
40c
40cc
40cb
34d
42
42a
38b
42c
42d
43

FIG. 3a

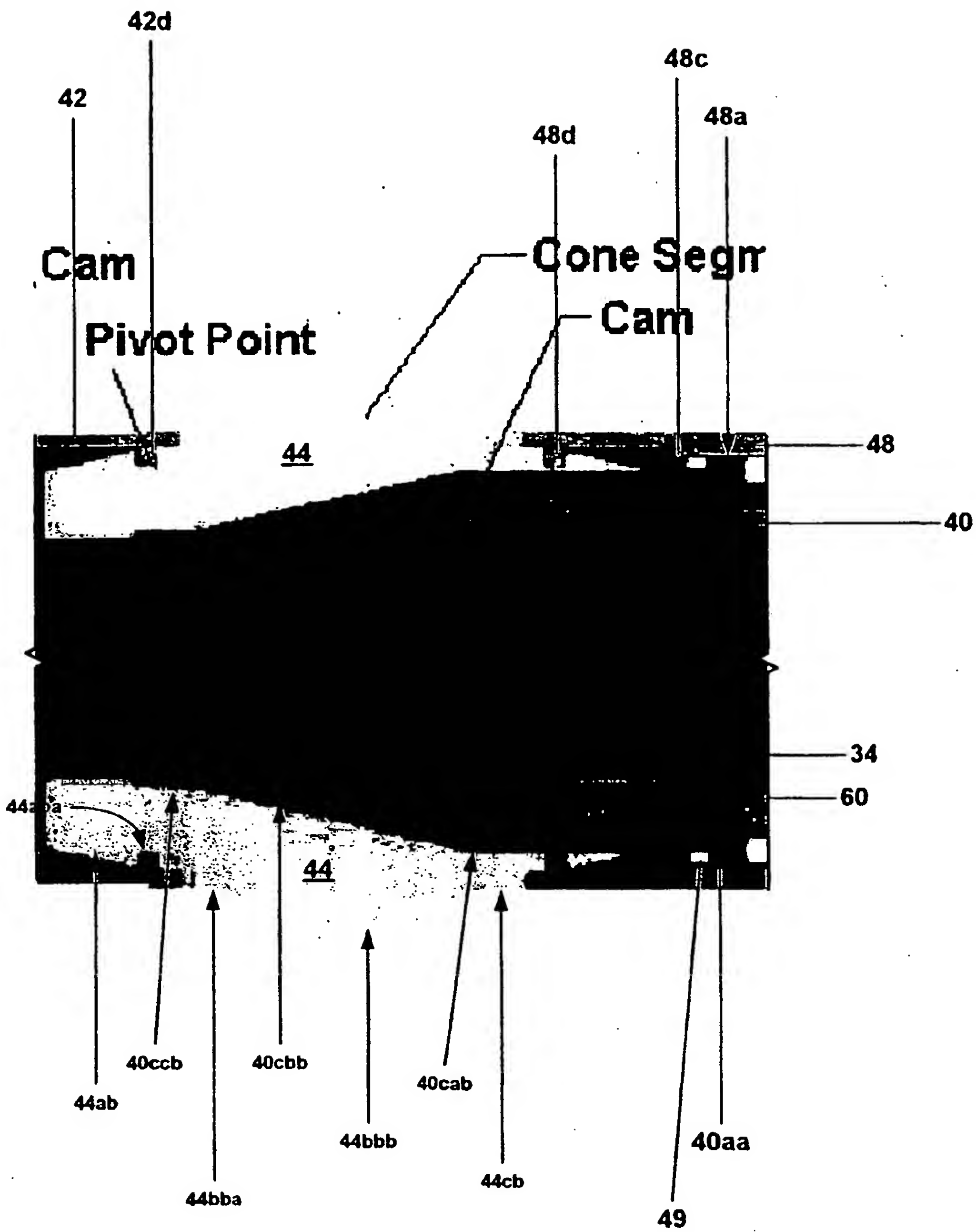

42d
42
48c
48a
48d
Cam
Cone Segm
Cam
Pivot Point
44
48
40
34
60
44
40ccb
40cbb
40cab
44ab
44bbb
40aa
44bba
44cb
49

FIG. 3b

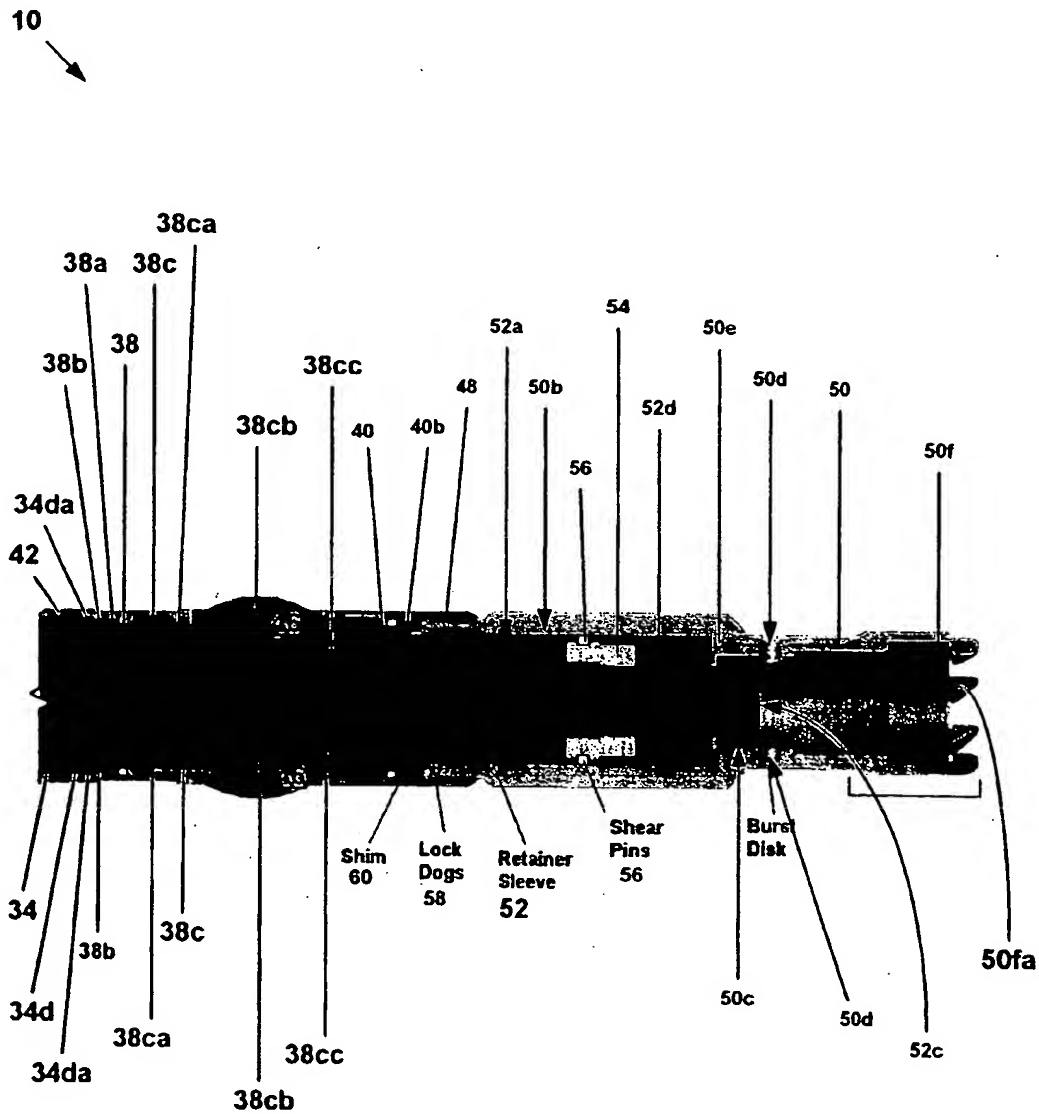

10
38ca
38a
38c
38
38b
38cc
38cb
40
40b
48
52a
50b
54
52d
50e
50d
50
50f
56
34da
42
34
34d
34da
38b
38ca
38c
38cb
38cc
Shim
60
Lock
Dogs
58
Retainer
Sleeve
52
Shear
Pins
56
Burst
Disk
50c
50d
52c
50fa

FIG. 4

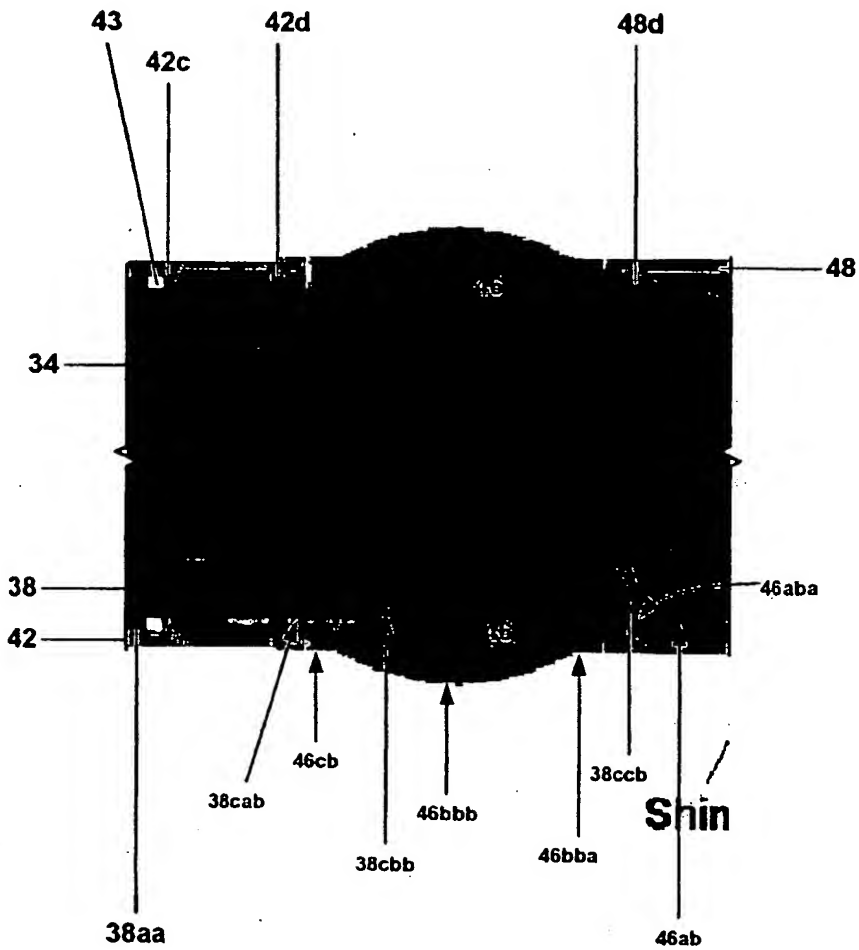

43
42c
42d
48d
48
34
38
42
46aba
46cb
38cab
46bbb
38cbb
46bba
38ccb
Shin
38aa
46ab

FIG. 4a

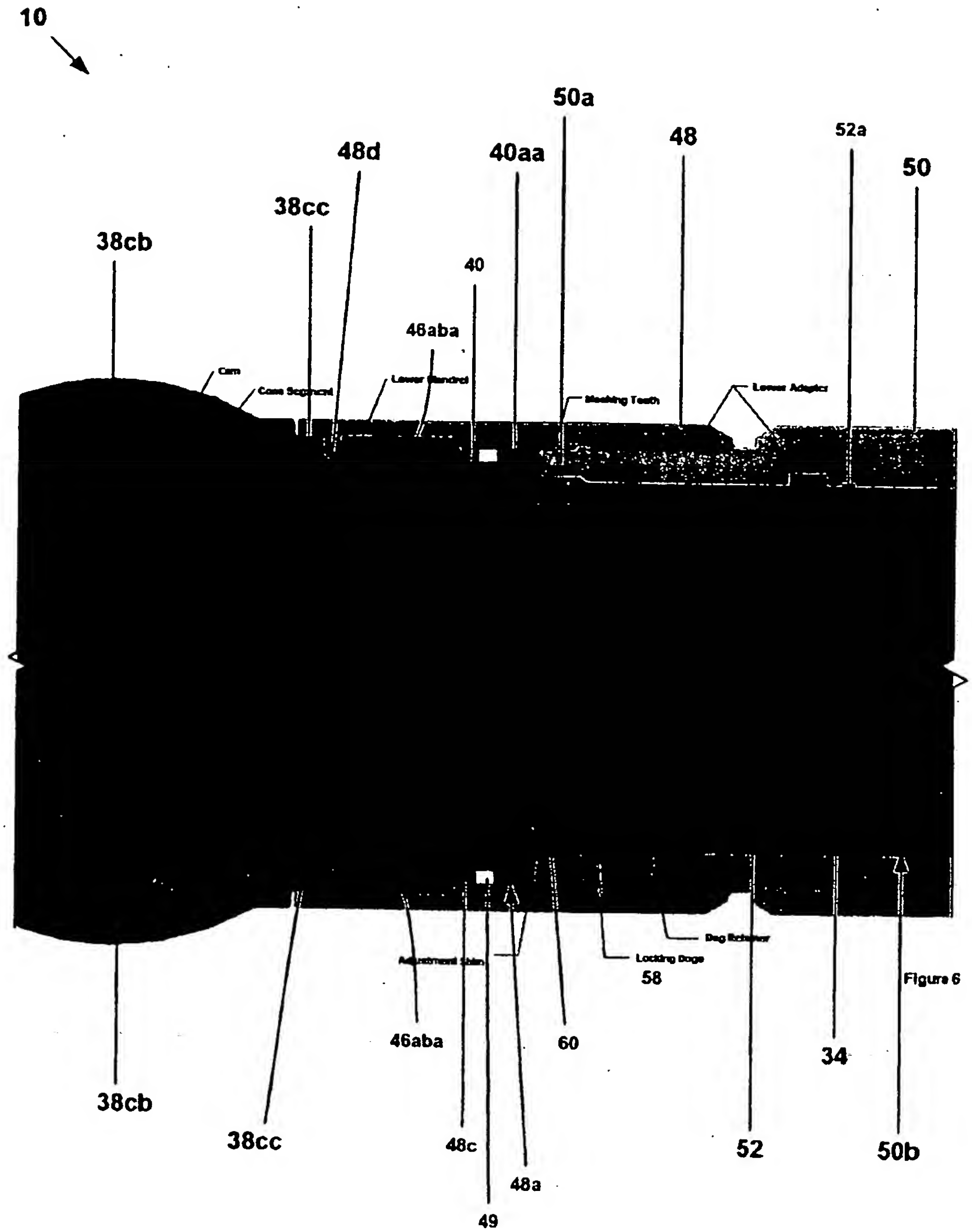

10
50a
48
52a
50
48d
40aa
38cc
38cb
40
46aba
Cam
Cam Segment
Lower Mandrel
Meshing Teeth
Lower Adaptor
Dog Retainer
Adjustment Shim
Locking Dogs
58
Figure 6
46aba
60
34
38cb
38cc
48c
52
50b
48a
49

FIG. 5

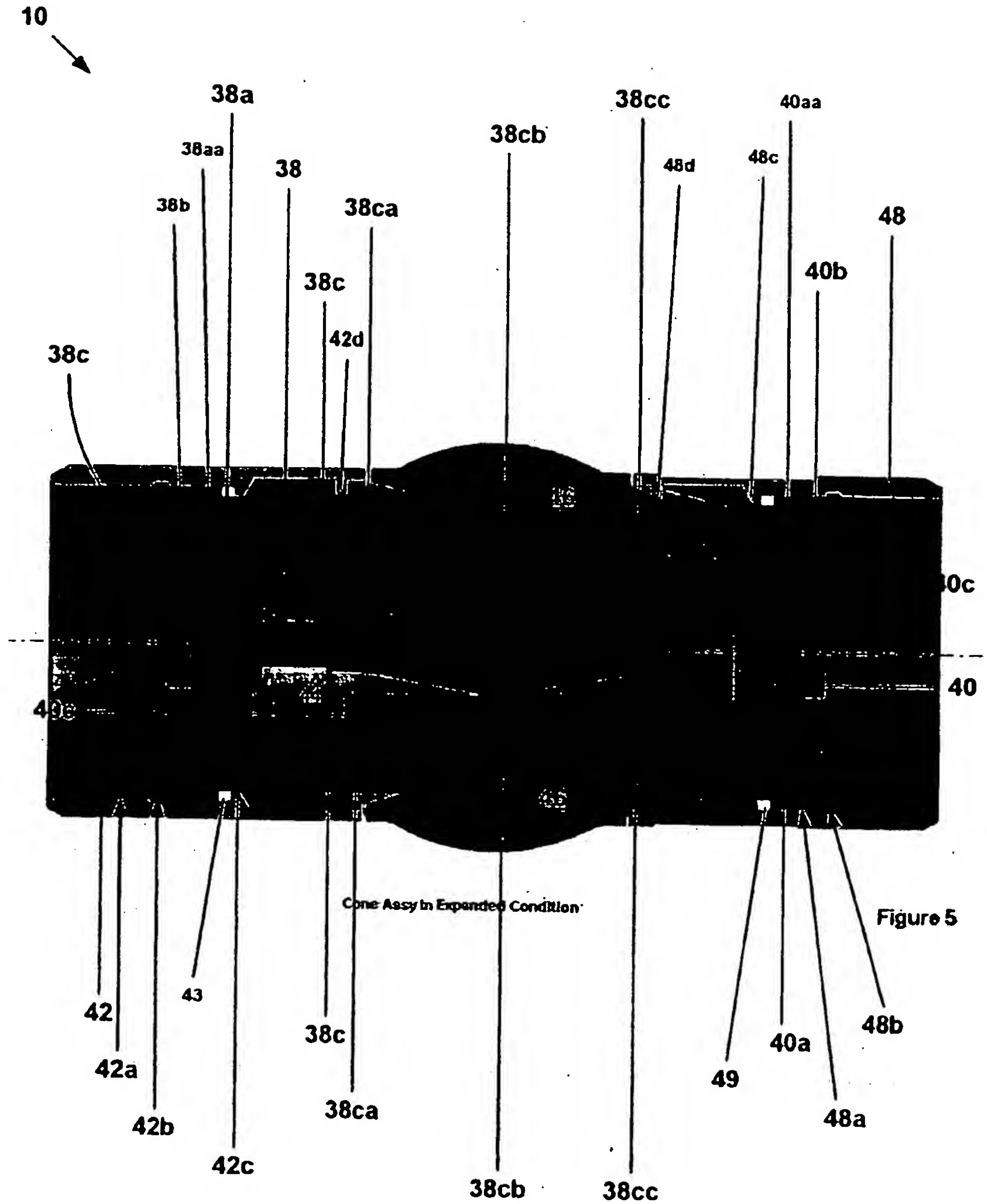
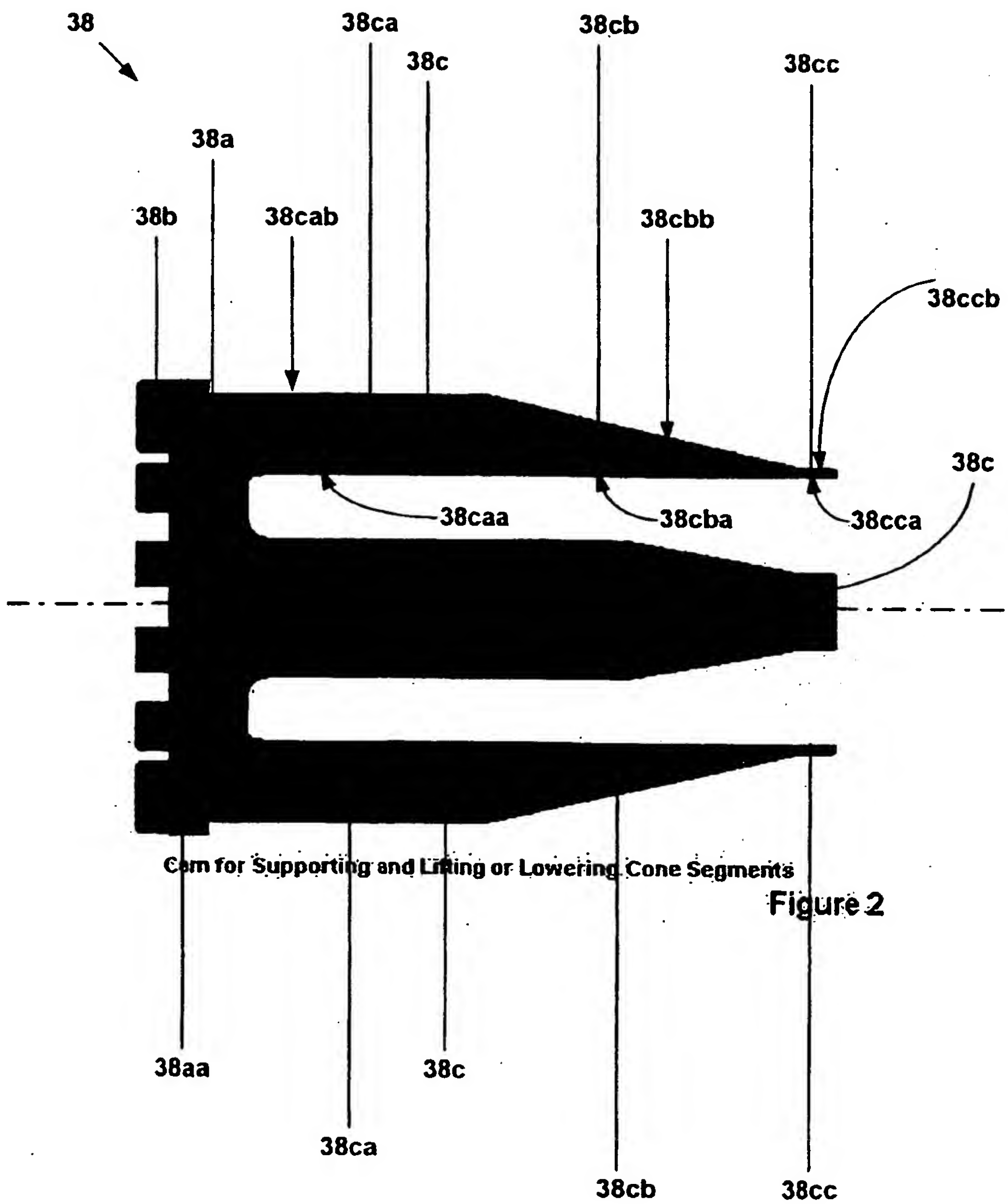

10
38a
38aa
38b
38
38ca
38c
42d
38c
38cb
38cc
48d
48c
40aa
48
40b
0c
40
Cone Assy In Expanded Condition
Figure 5
42
43
42a
42b
42c
38c
38ca
38cb
38cc
49
40a
48a
48b

FIG. 6



Cam for Supporting and Lifting or Lowering Cone Segments

Figure 2

FIG. 7a

38

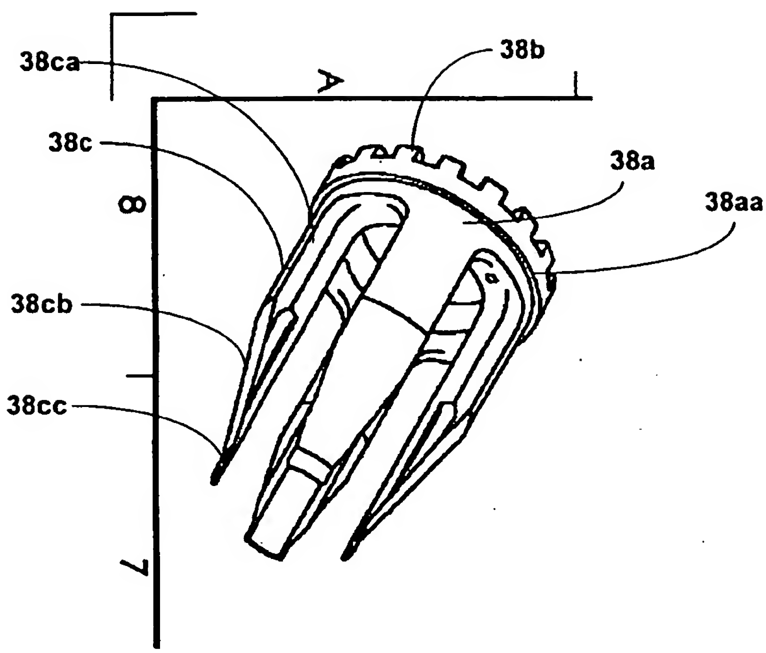


FIG. 7b

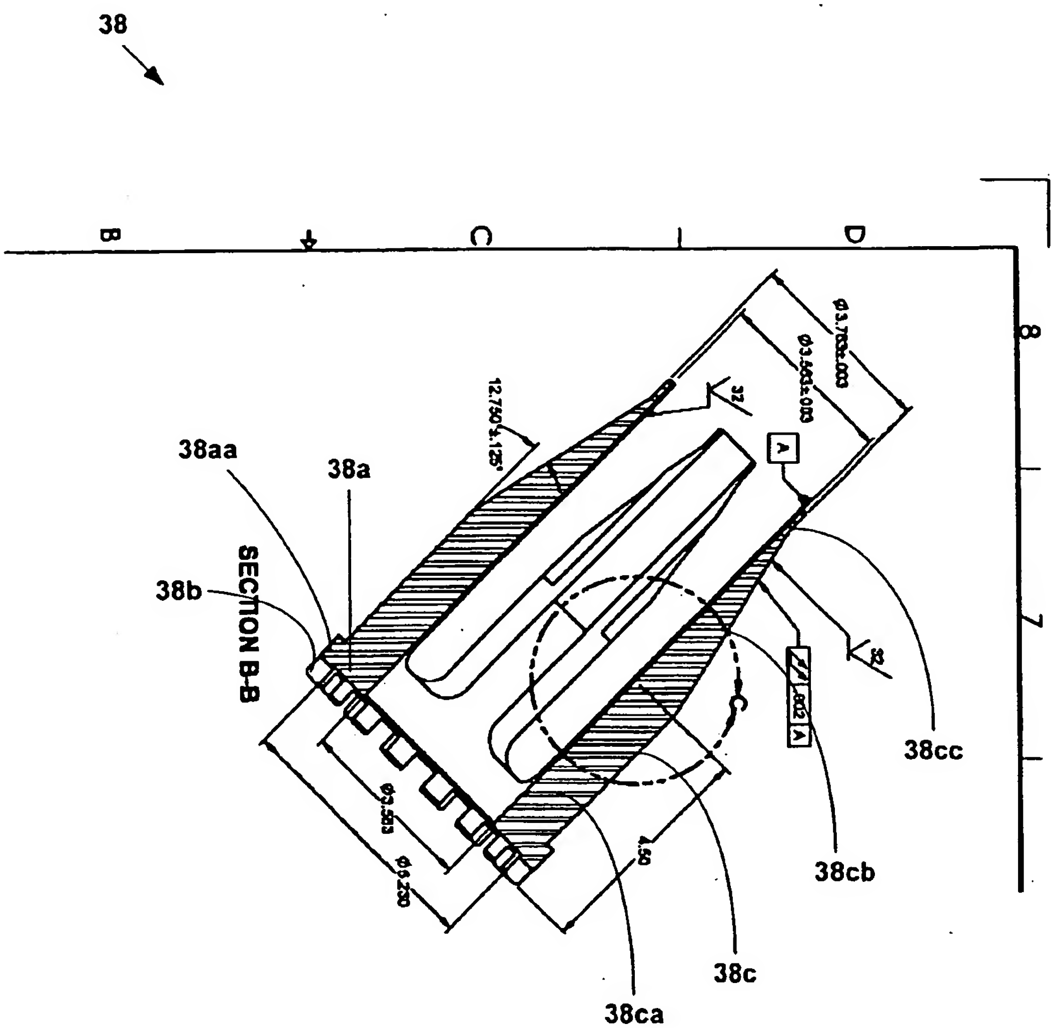


FIG. 7c

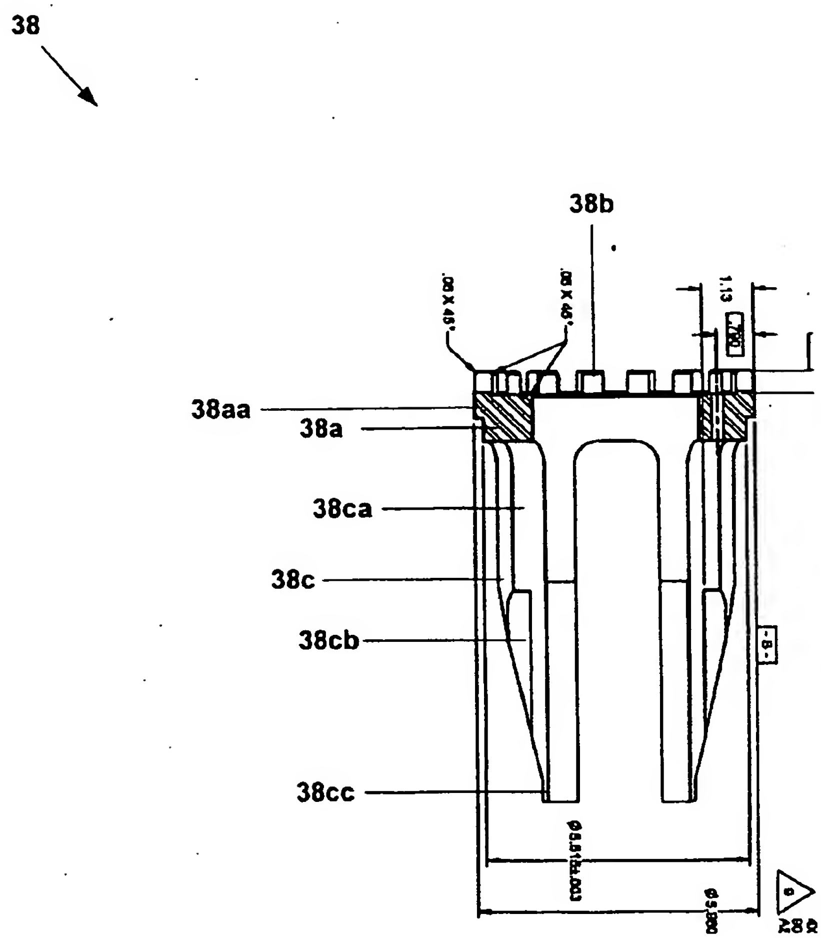


FIG. 7d

38

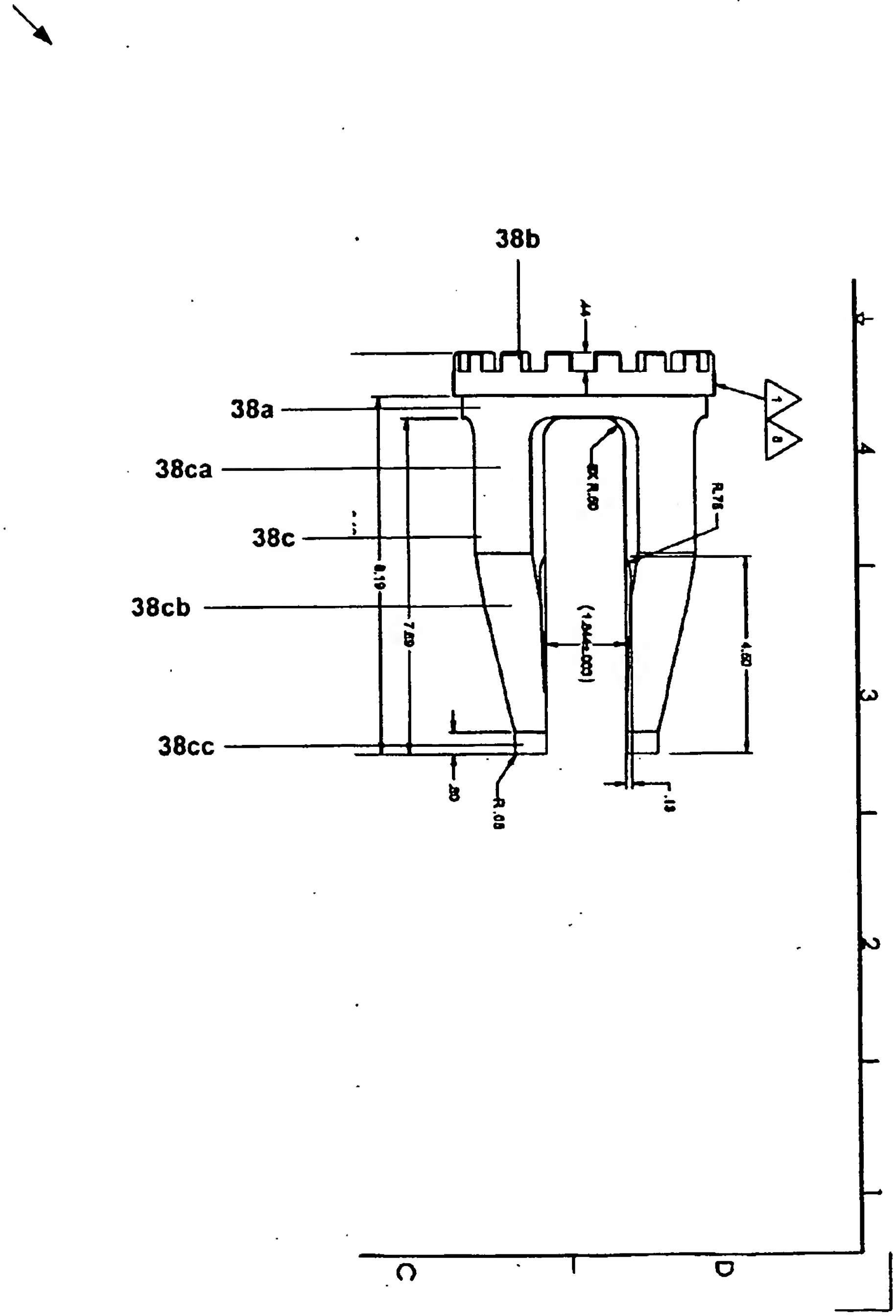


FIG. 7e

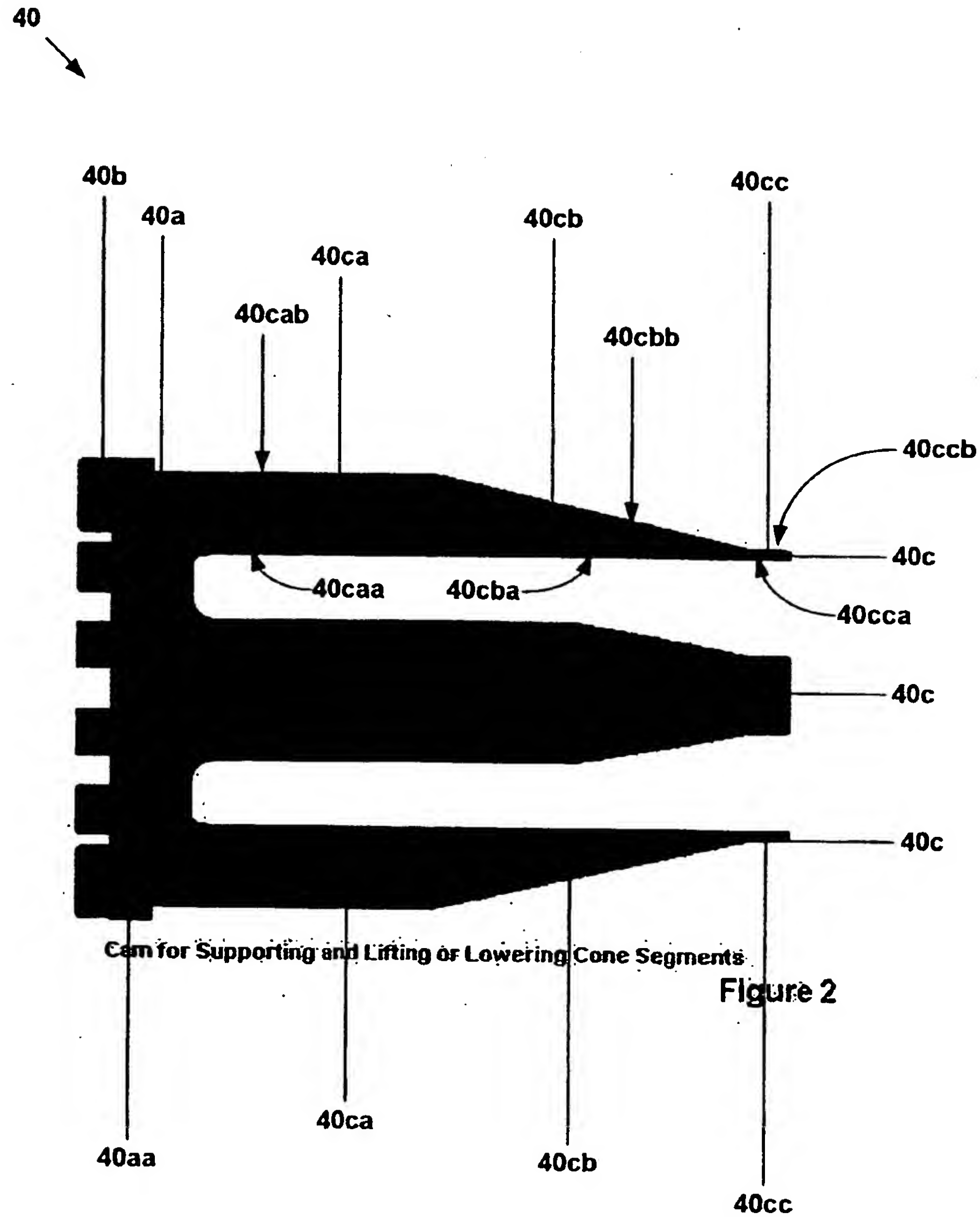

40
40b
40a
40ca
40cab
40cb
40cbb
40cc
40ccb
40c
40caa
40cba
40cca
40c
40c
Cam for Supporting and Lifting or Lowering Cone Segments
Figure 2
40aa
40ca
40cb
40cc

FIG. 7f

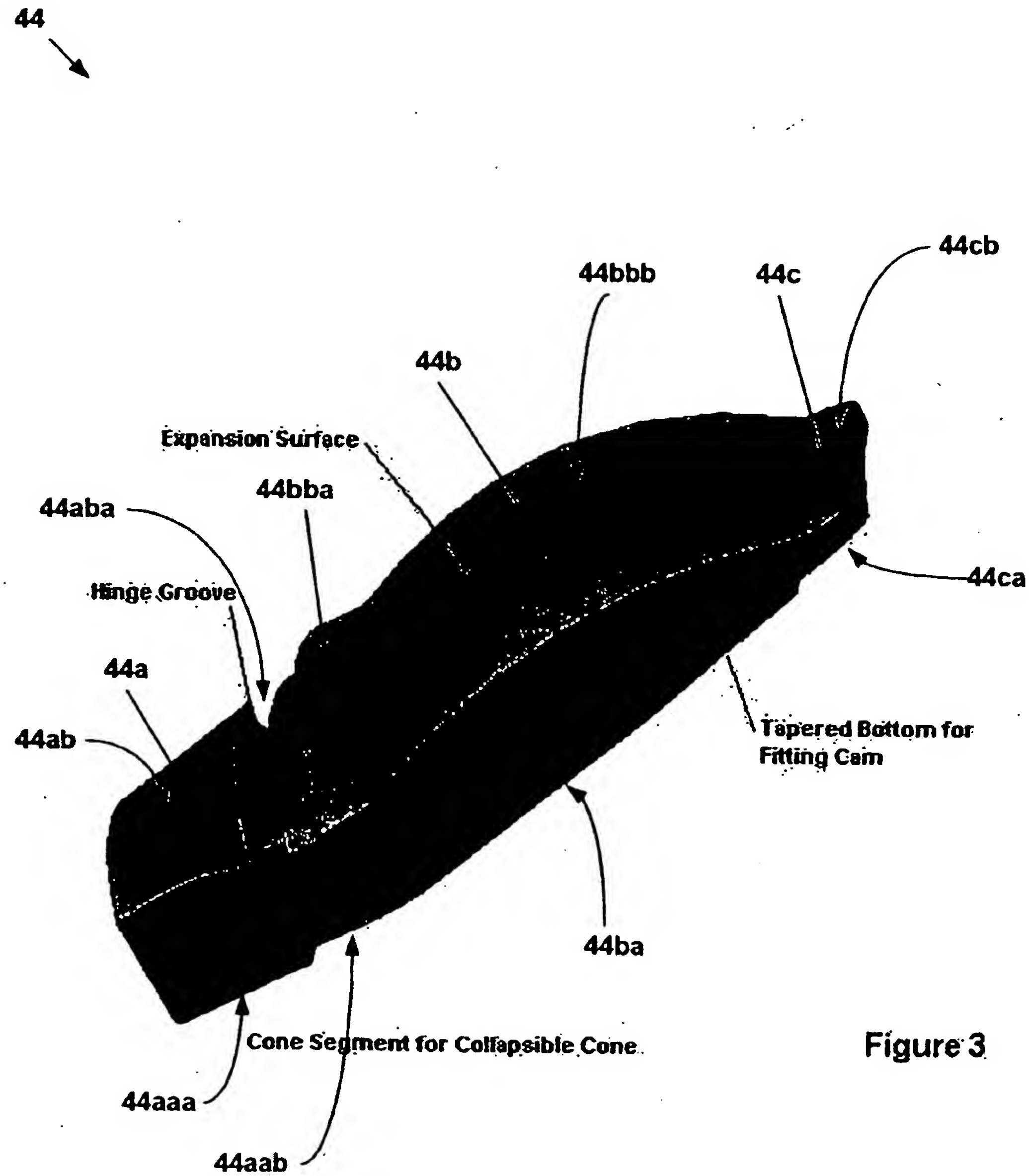


Figure 3

FIG. 8a

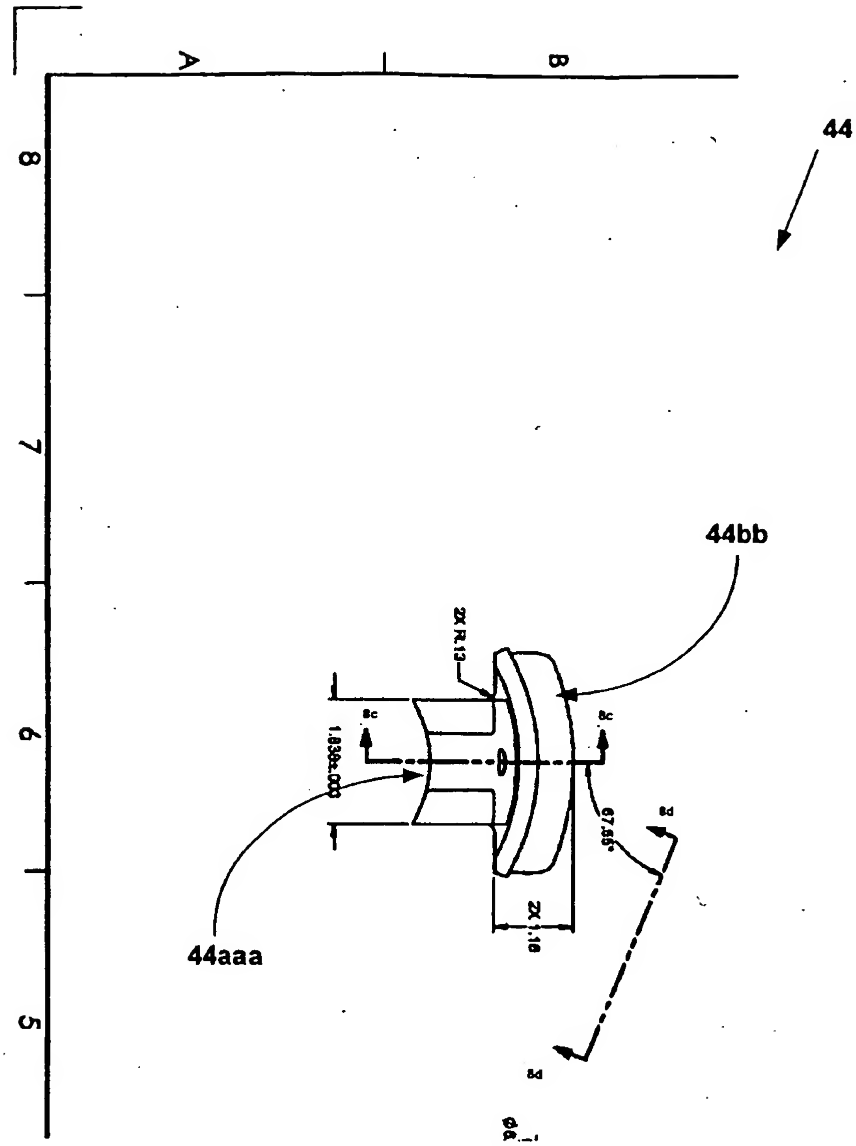
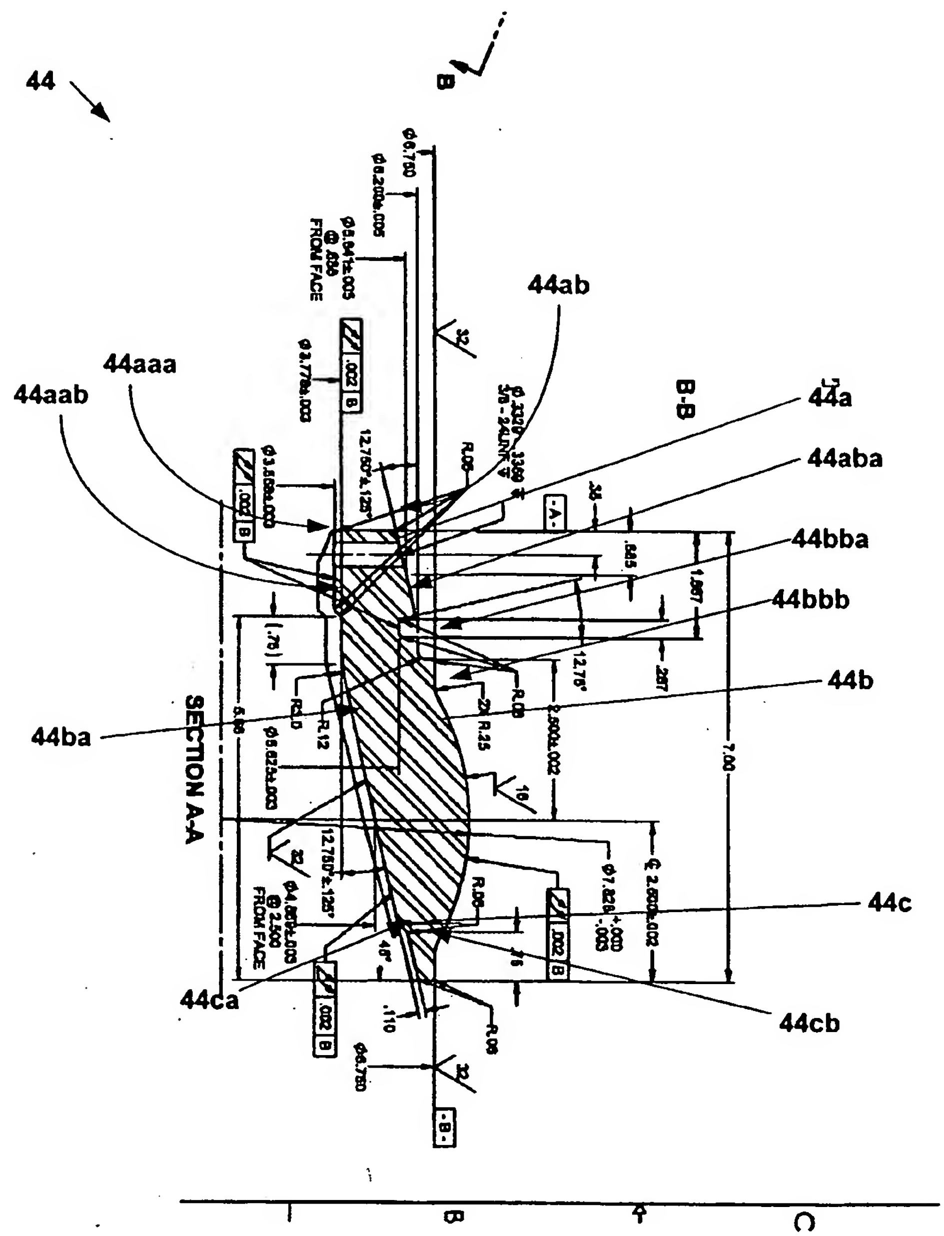


FIG. 8b


44
44ab
44aaa
44aab
44a
44aba
44bba
44bbb
44b
44ba
SECTION A-A
B-B
44c
44ca
44cb

i. 8c

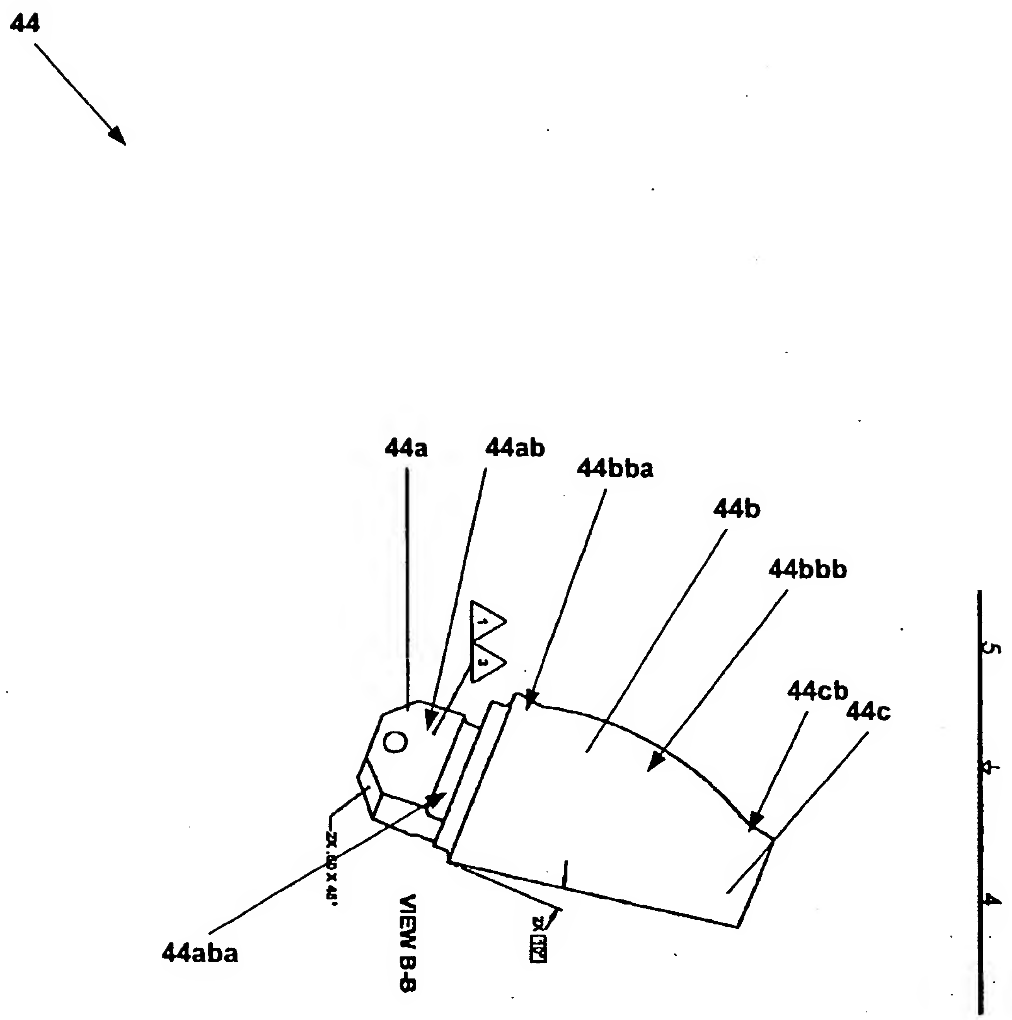


FIG. 8d

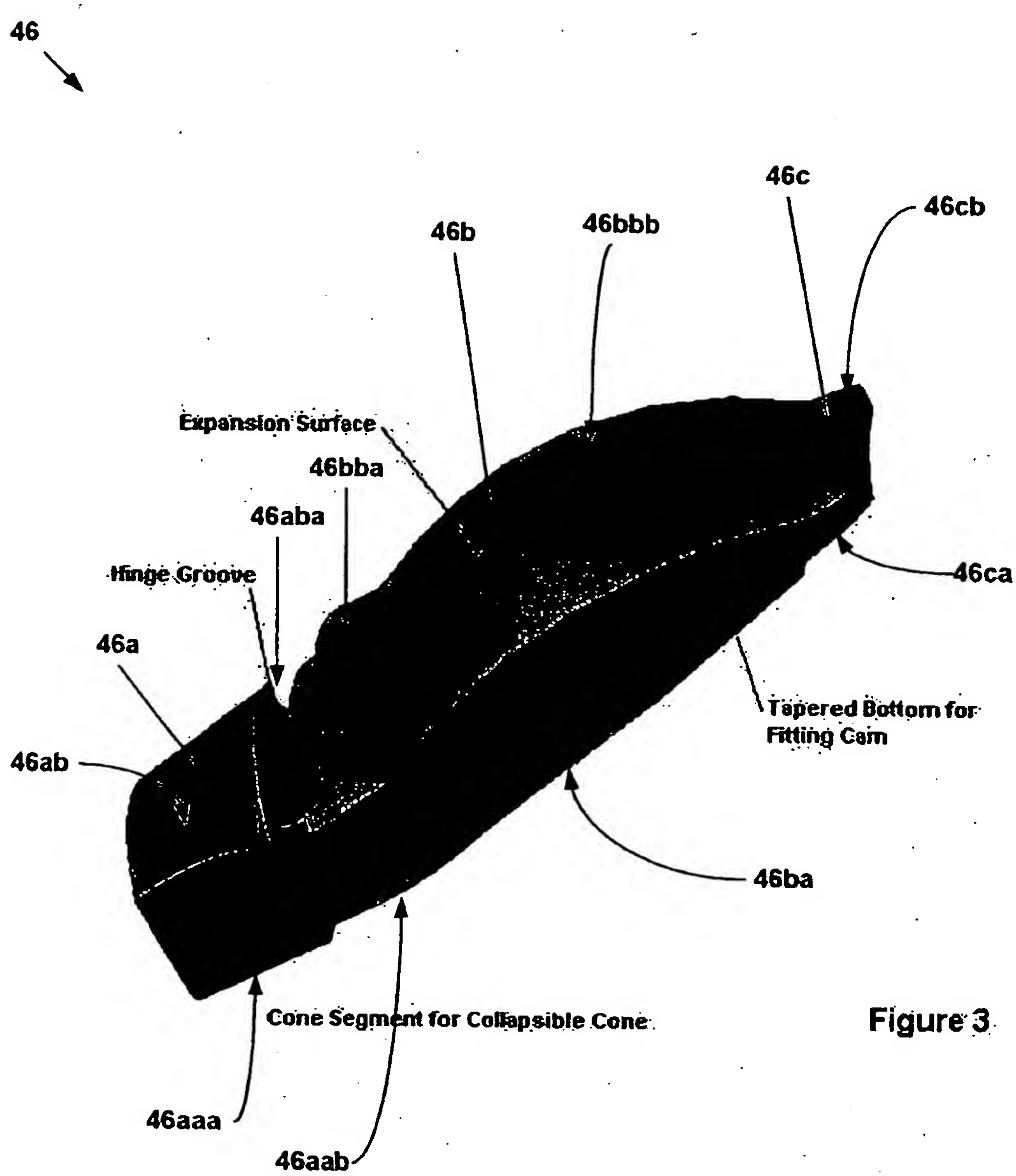


Figure 3

FIG. 8e

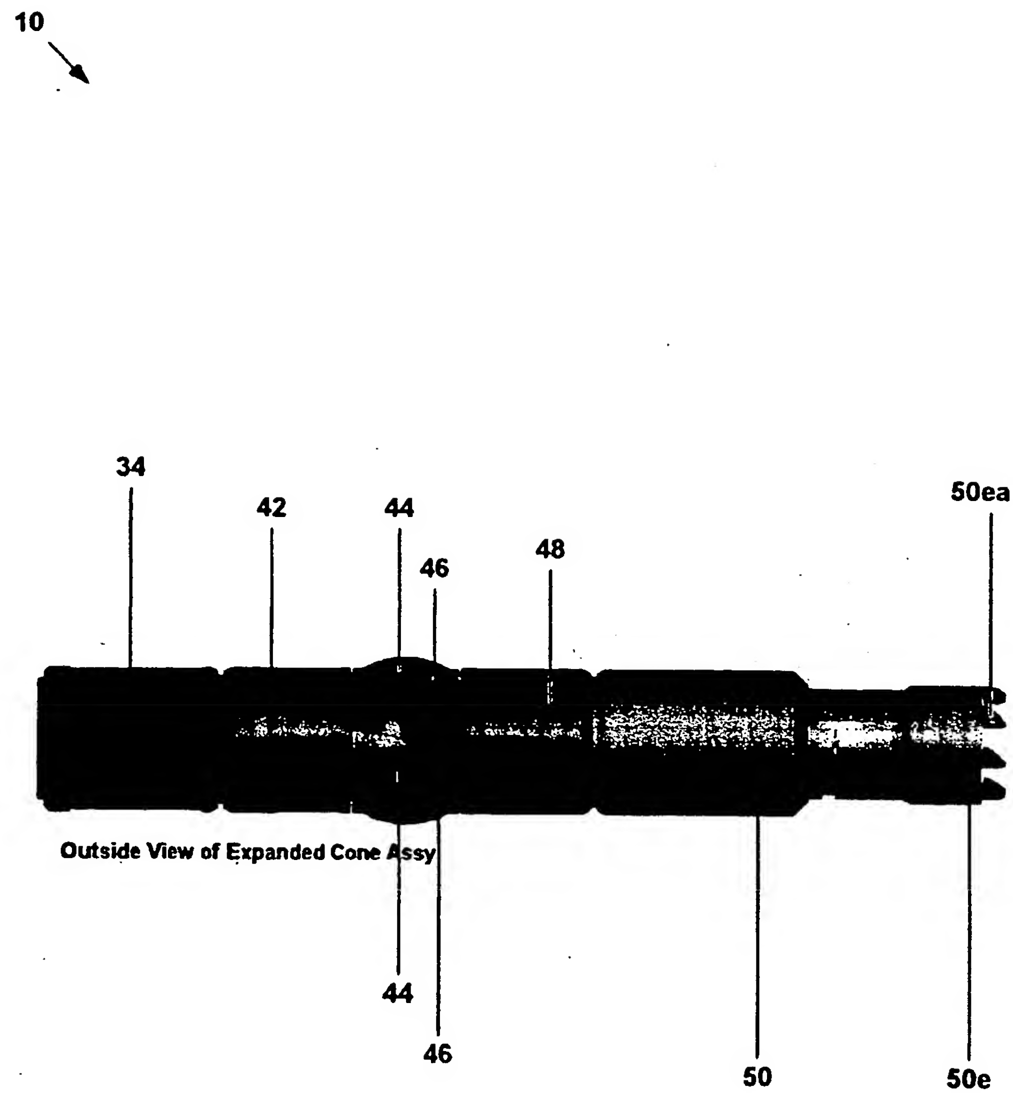

10
34
42
44
46
48
50ea
Outside View of Expanded Cone Assy
44
46
50
50e

FIG. 9

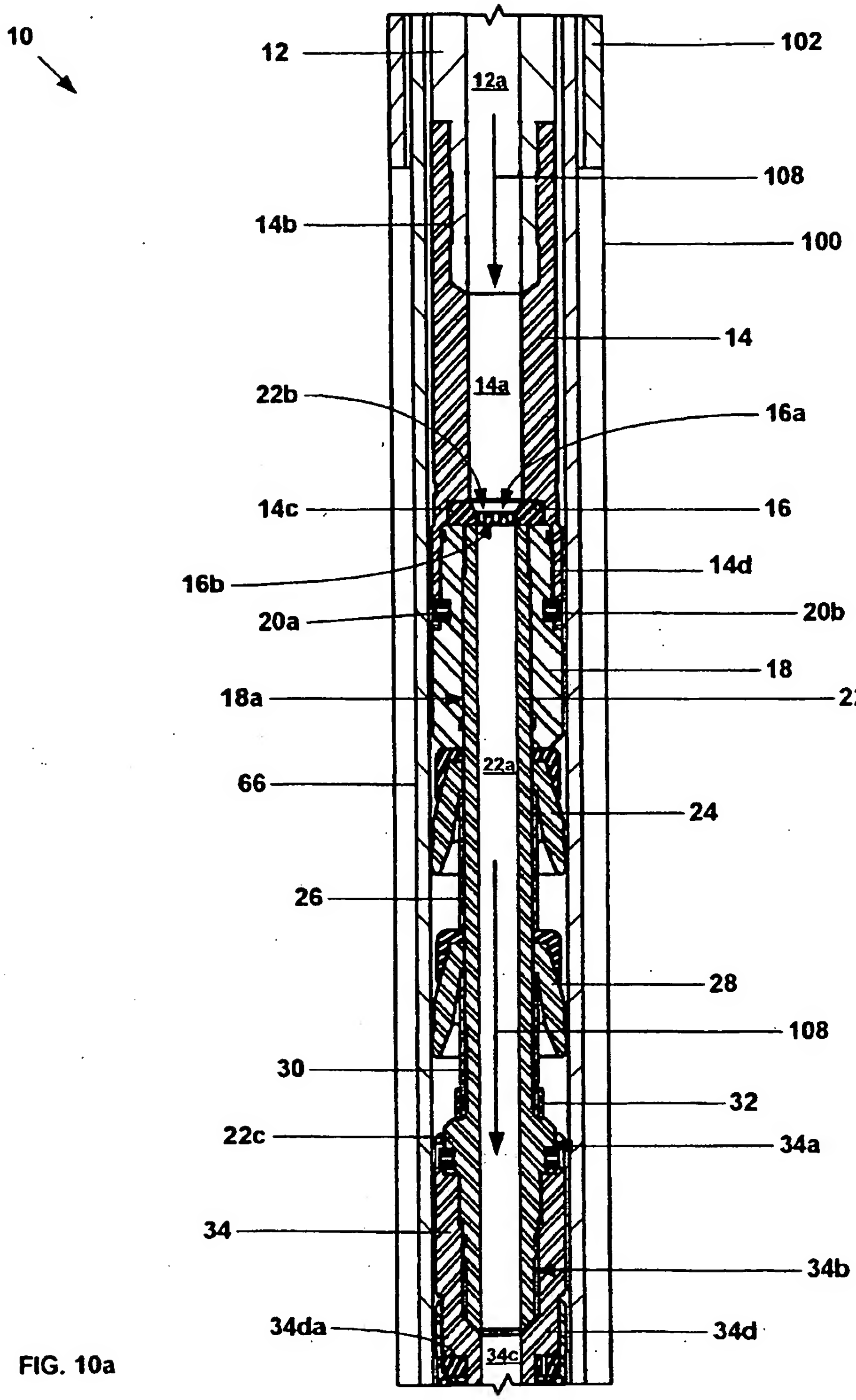

10
12
12a
102
108
14b
100
14
14a
22b
16a
14c
16
16b
14d
20a
20b
18
18a
22
22a
66
24
26
28
108
30
32
22c
34a
34
34b
34da
34c
34d

FIG. 10a

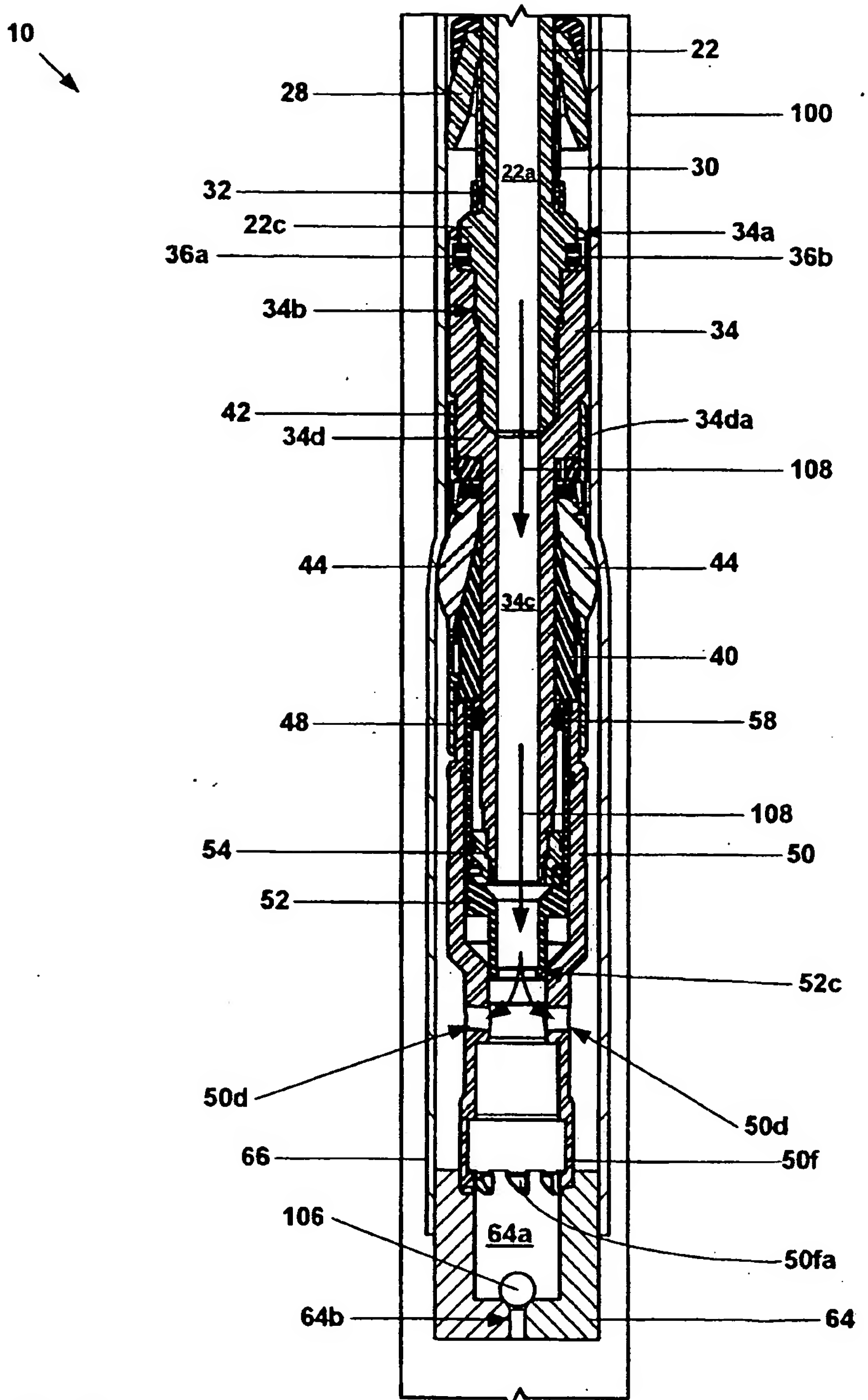

10
22
28
100
22a
30
32
22c
34a
36a
36b
34b
34
42
34da
34d
108
44
44
34c
40
48
58
108
54
50
52
52c
50d
50d
66
50f
106
64a
50fa
64b
64

FIG. 10b

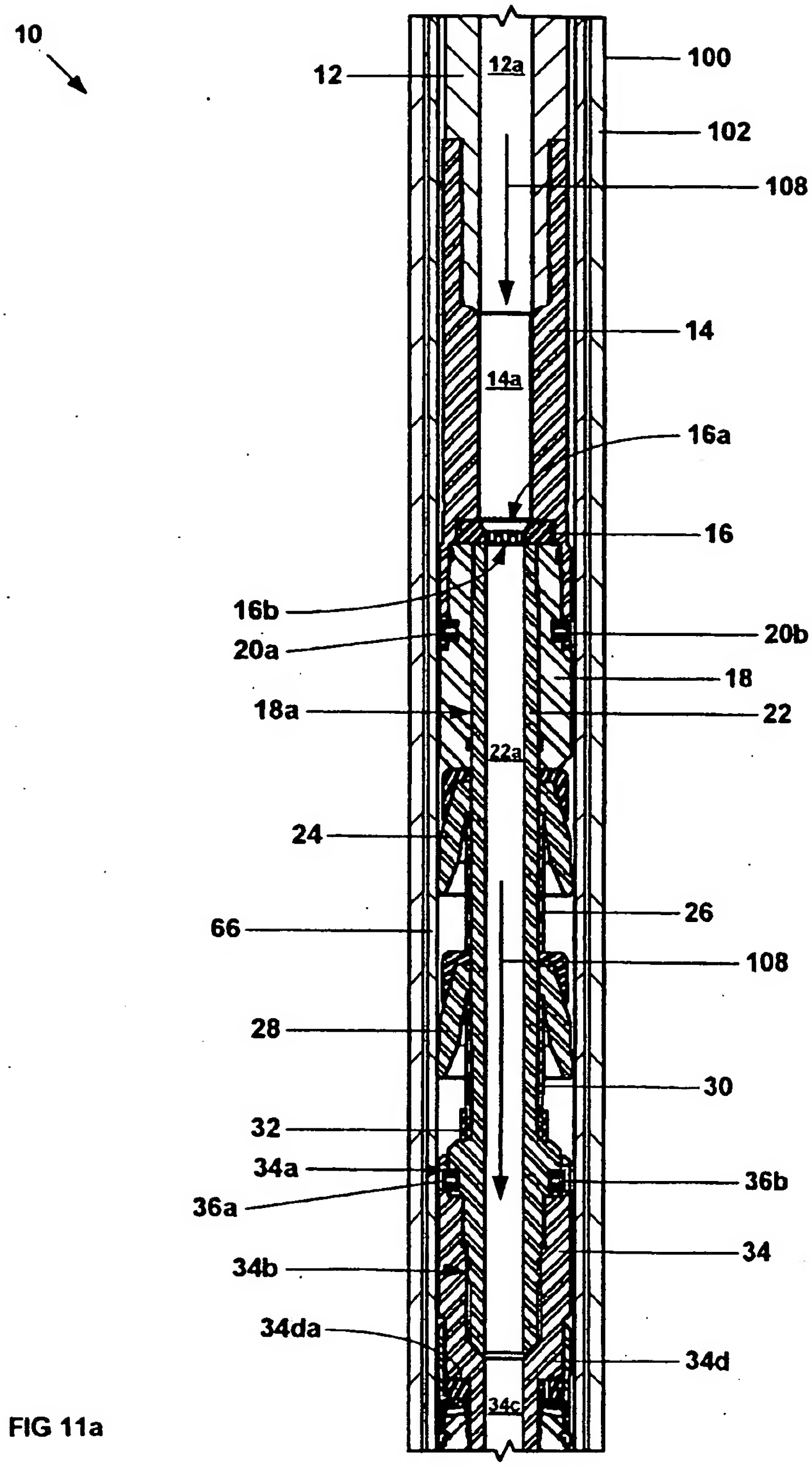

10
12
12a
100
102
108
14
14a
16a
16
16b
20a
20b
18
18a
22
22a
24
26
66
108
28
30
32
34a
36b
36a
34
34b
34da
34d
34c

FIG 11a

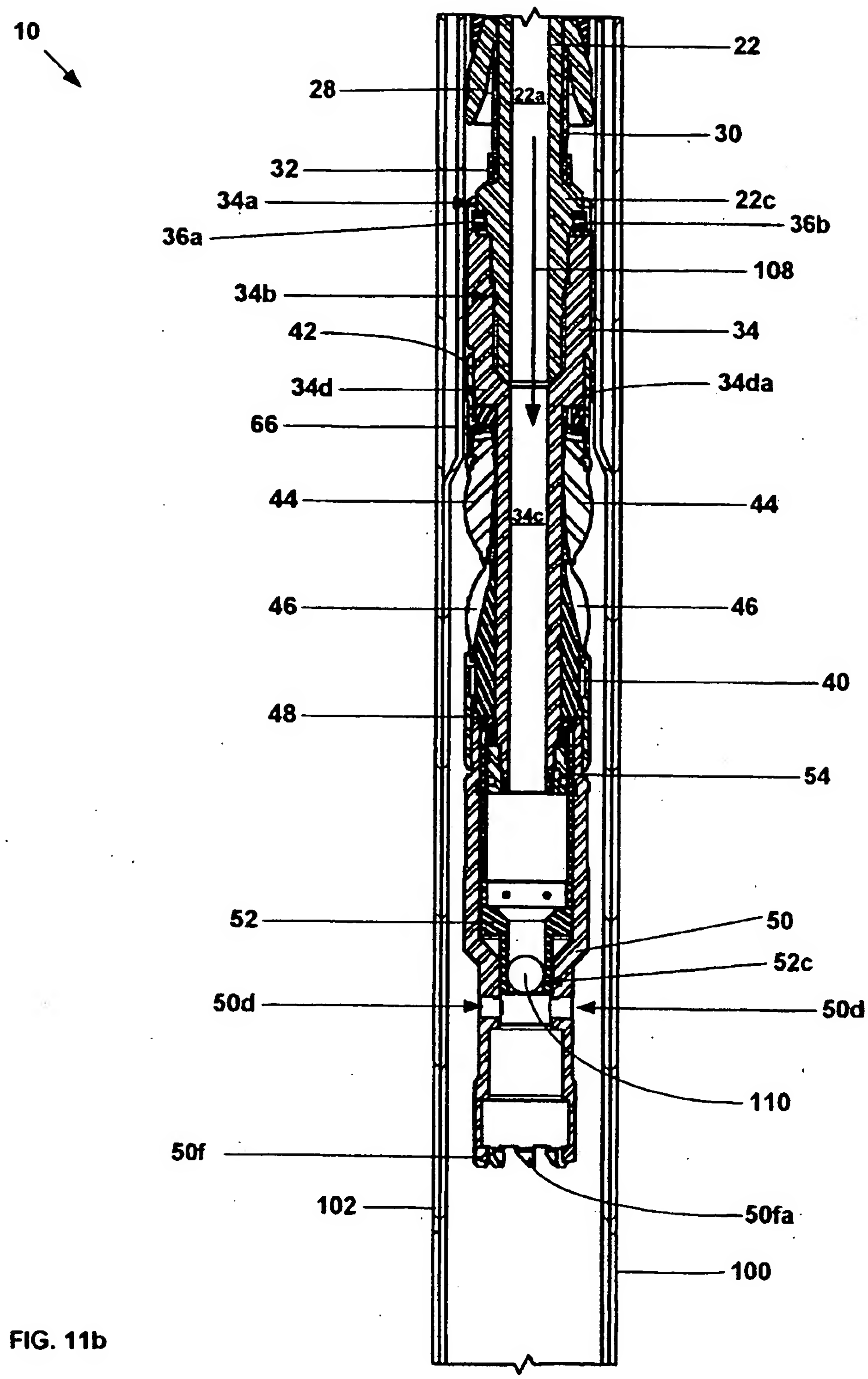

10
22
28
22a
30
32
34a
22c
36a
36b
108
34b
42
34
34d
34da
66
44
34c
44
46
46
40
48
54
52
50
52c
50d
50d
110
50f
102
50fa
100

FIG. 11b

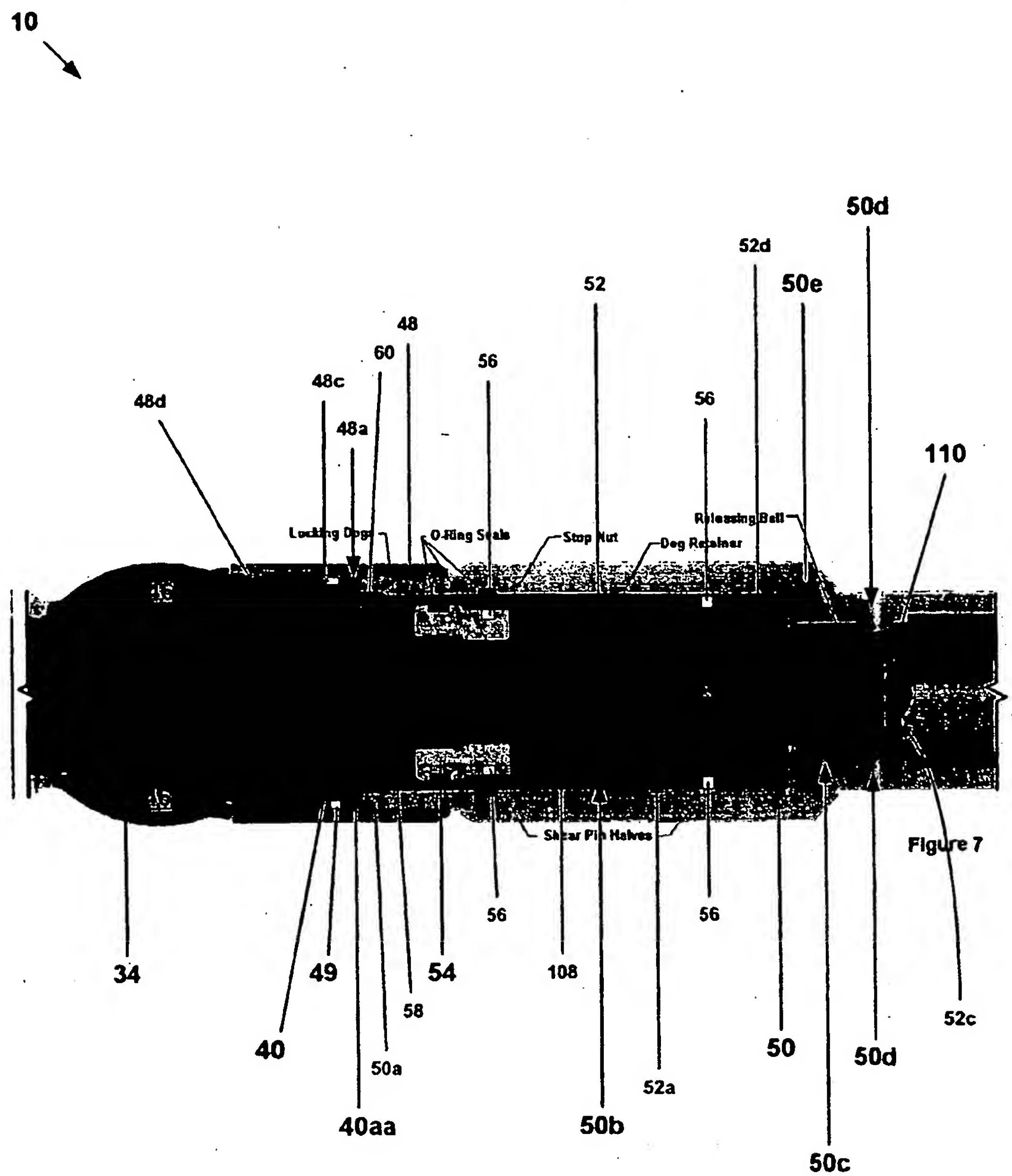

10
50d
52d
52
50e
48
60
56
48c
48d
56
48a
110
Locking Dogs
O-Ring Seals
Stop Nut
Dog Retainer
Releasing Ball
Shear Pin Halves
Figure 7
56
56
34
49
54
108
58
40
52c
50
50d
50a
52a
40aa
50b
50c

FIG. 12

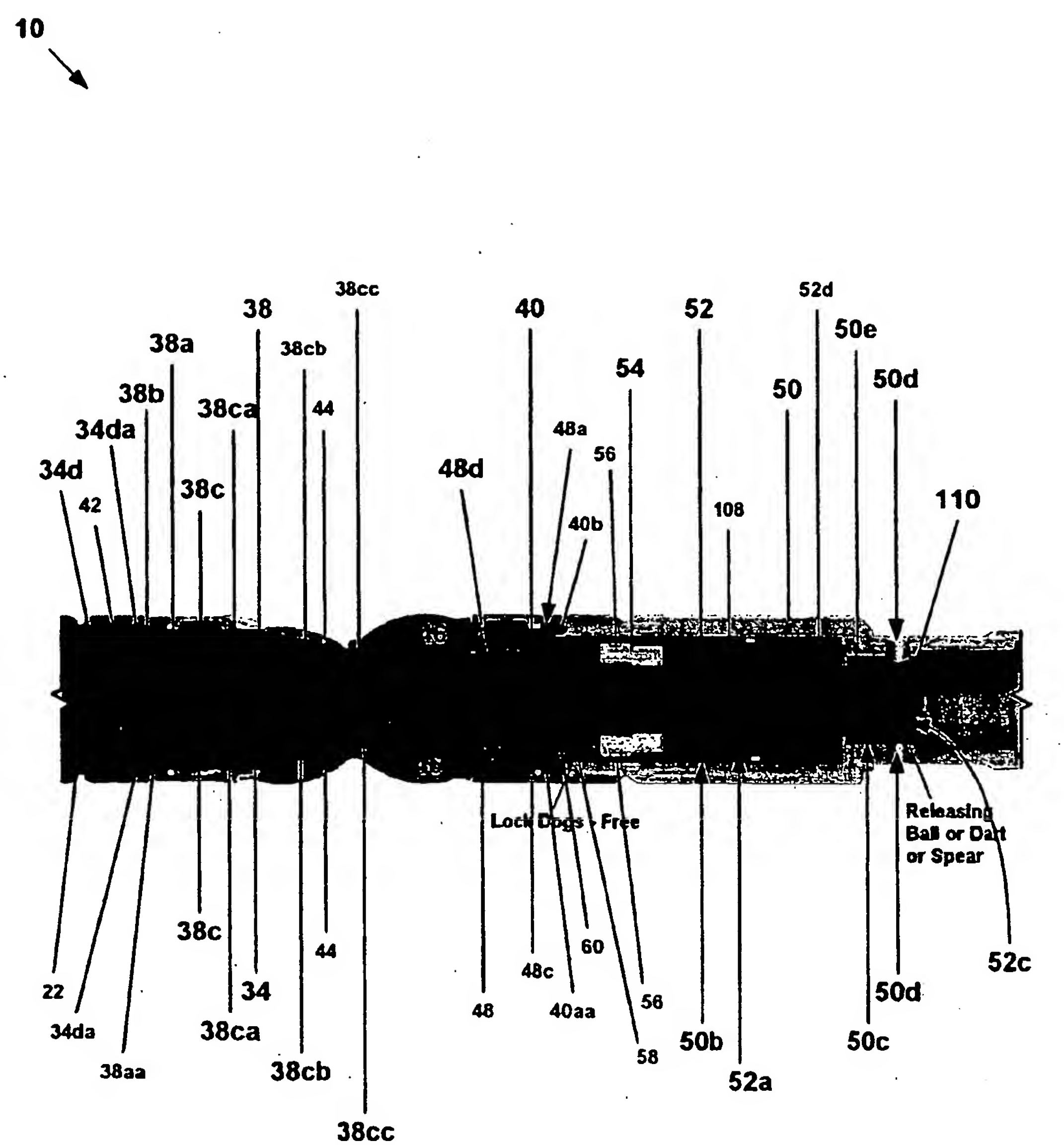

10
38cc
38
40
52
52d
38a
38cb
50e
54
50d
38b
38ca
44
50
34da
48a
34d
48d
56
38c
42
40b
108
110
Lock Dogs - Free
Releasing Ball or Dart or Spear
38c
60
44
52c
48c
34
50d
22
56
40aa
48
34da
38ca
50b
50c
58
38aa
38cb
52a
38cc

FIG. 13

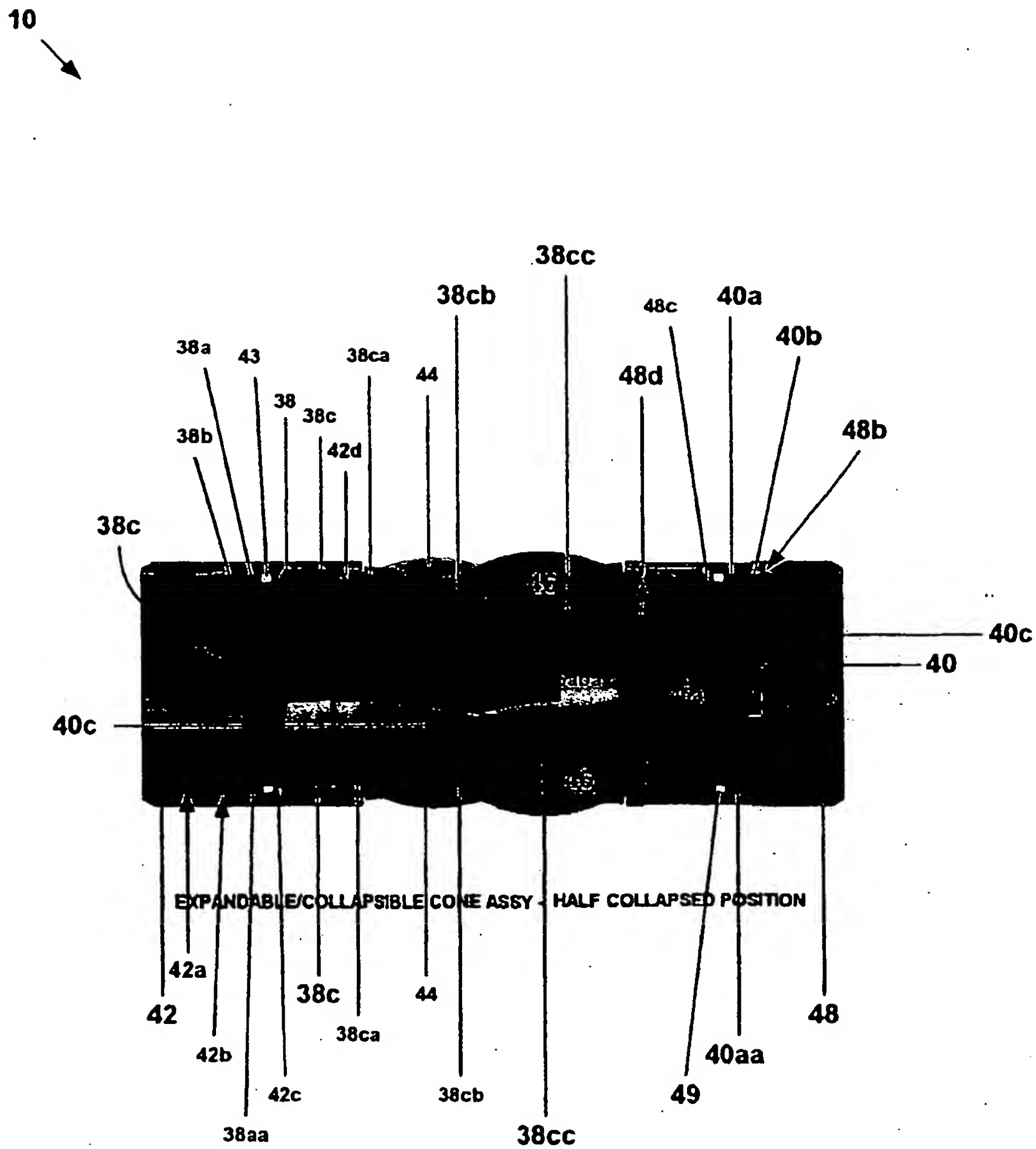
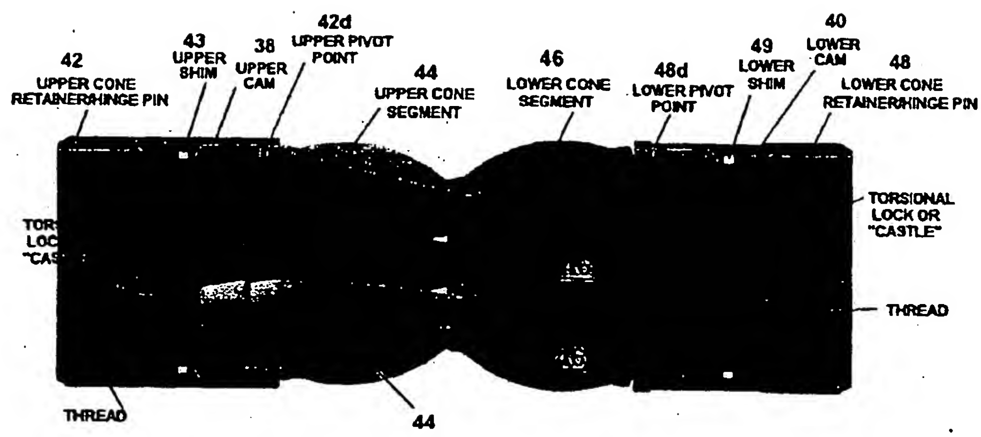

10
38cc
38cb
48c
40a
40b
38a
43
38ca
44
48d
38
38c
38b
42d
48b
38c
40c
40
40c
EXPANDABLE/COLLAPSIBLE CONE ASSY - HALF COLLAPSED POSITION
42a
42
38c
44
48
38ca
42b
40aa
42c
38cb
49
38aa
38cc

FIG. 14

10



EXPANDABLE/COLLAPSIBLE CONE ASSY - FULL COLLAPSED POSITION

FIG. 15

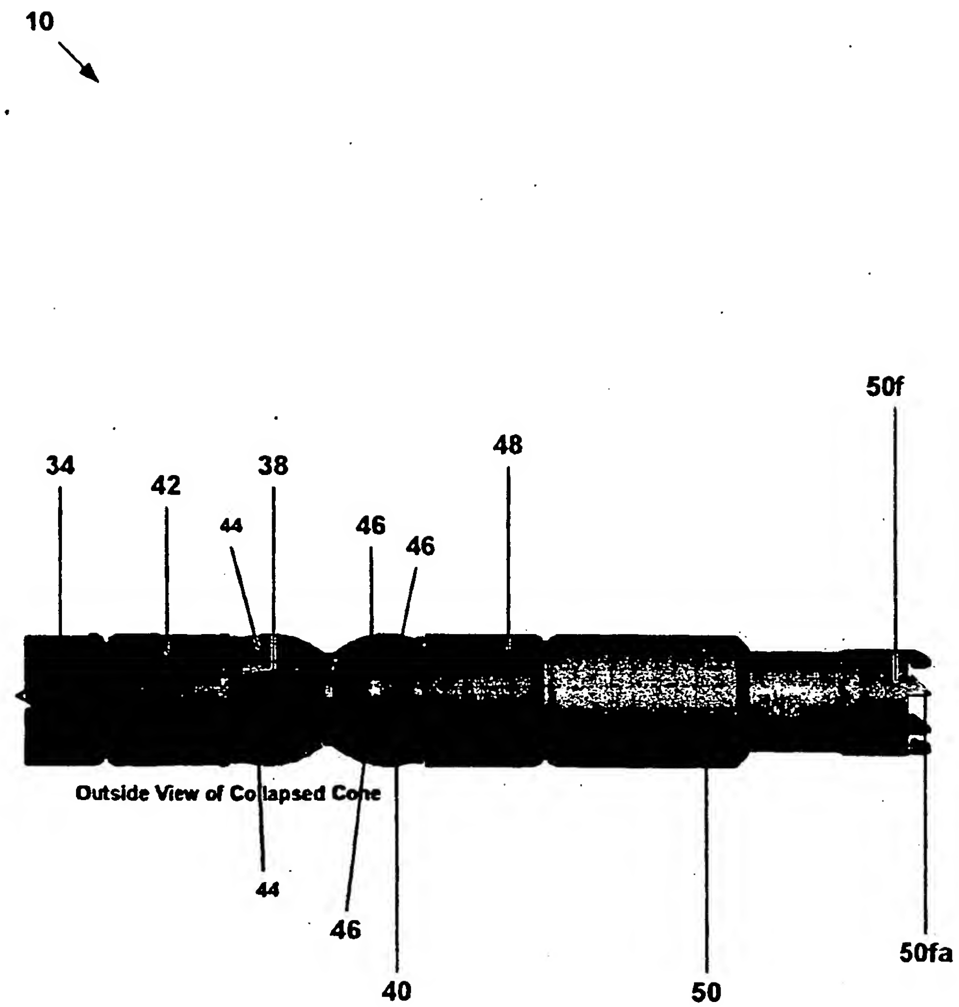

10
34
42
44
38
46
46
48
50f
Outside View of Collapsed Cone
44
46
40
50
50fa

FIG. 16

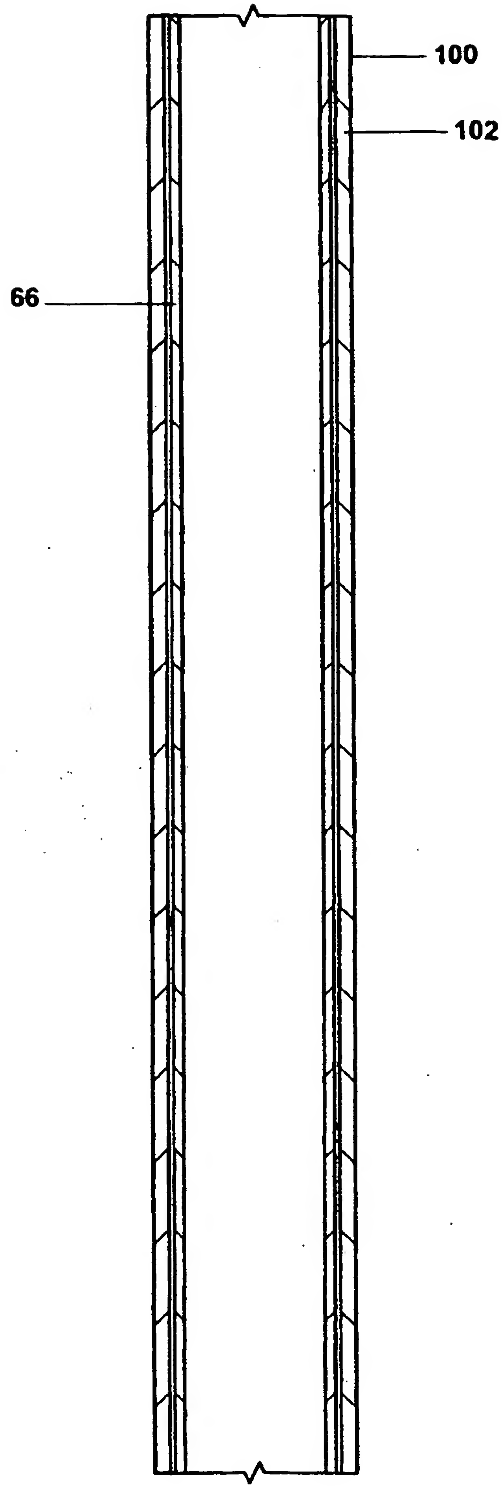


FIG 17a

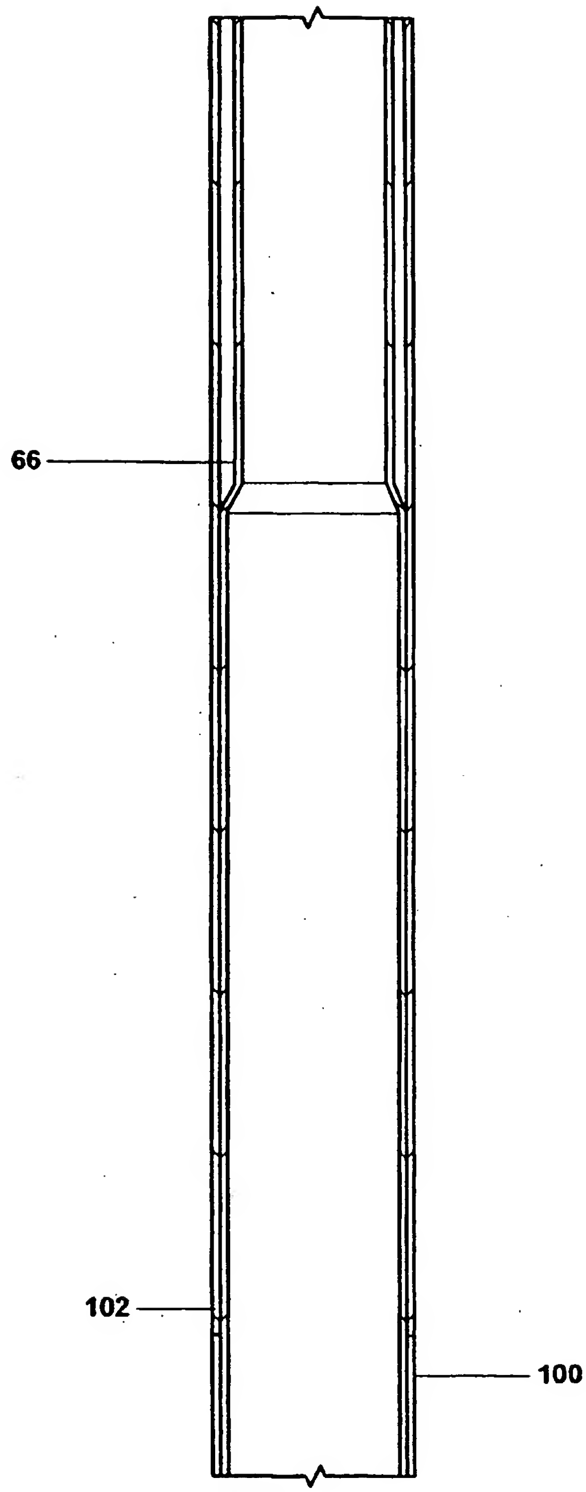


FIG. 17b

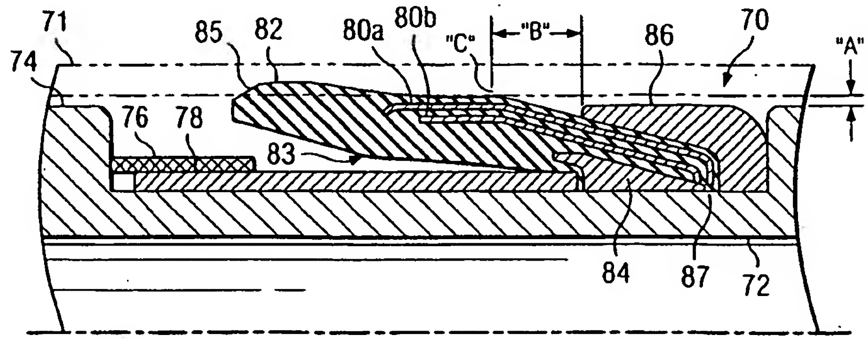


Fig. 18

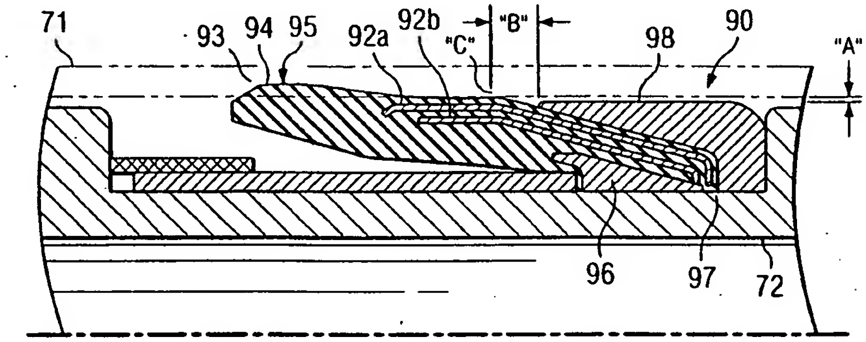


Fig. 19a

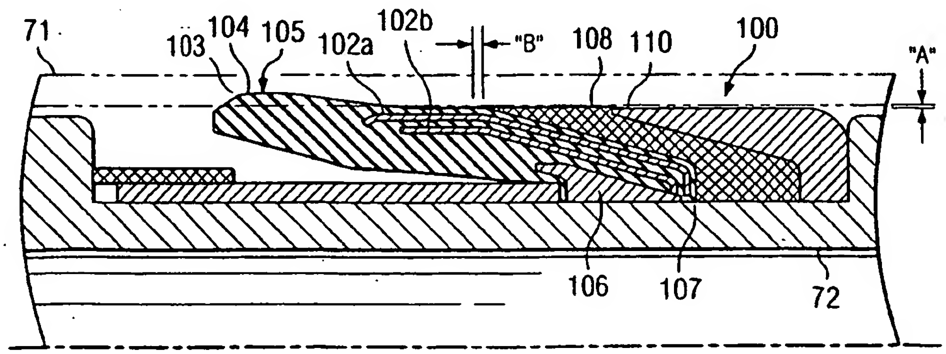


Fig. 19b

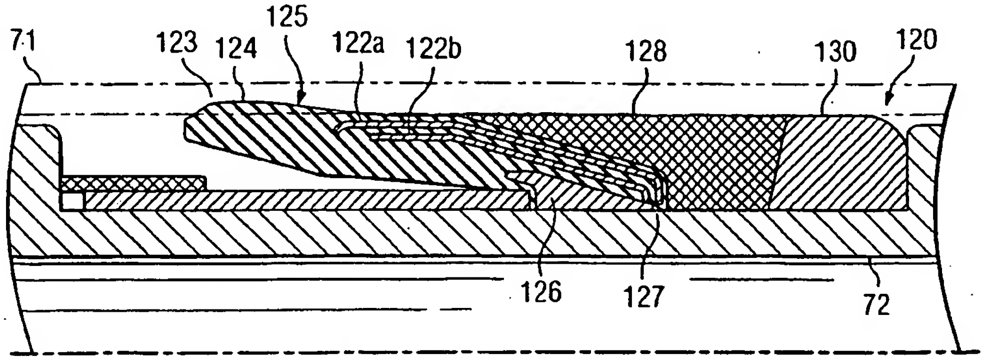


Fig. 19c

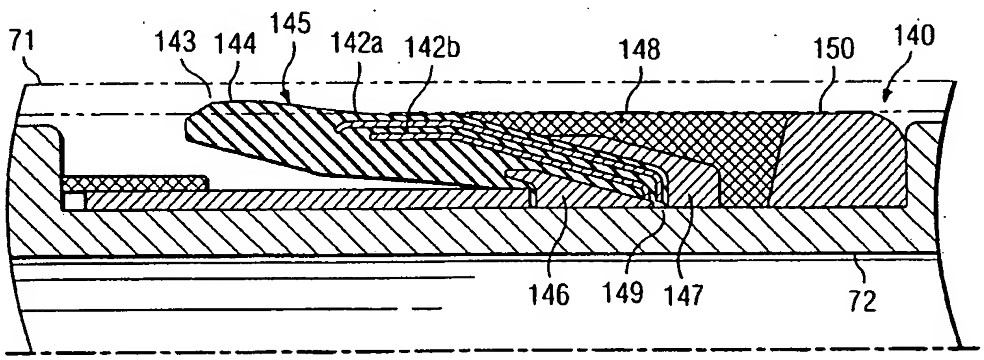


Fig. 19d

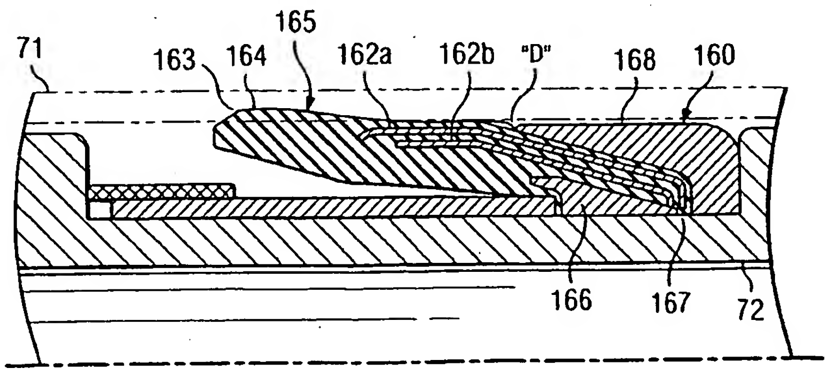


Fig. 19e

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(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
24 December 2003 (24.12.2003)

PCT

(10) International Publication Number
WO 2003/106130 A3

(51) International Patent Classification[7]: E21B 43/10

(21) International Application Number: PCT/US2003/018530

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(25) Filing Language: English

(26) Publication Language: English

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60/387,961 12 June 2002 (12.06.2002) US

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(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

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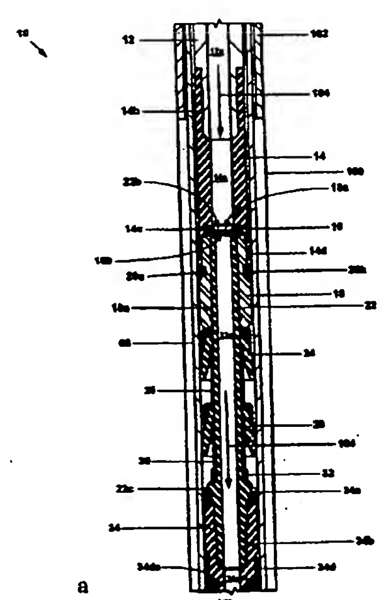
[Continued on next page]

(54) Title: COLLAPSIBLE EXPANSION CONE



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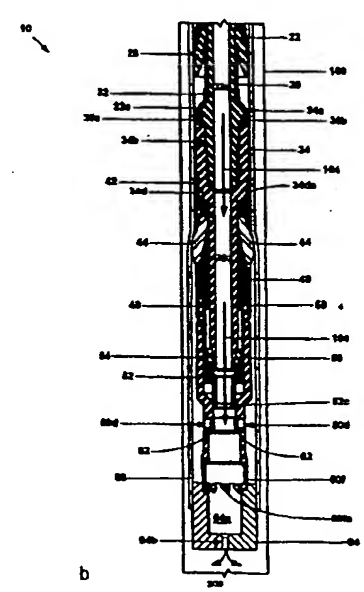

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WO 2003/106130 A3

(57) Abstract: An apparatus (910) for radially expanding and plastically deforming an expandable tubular member (66) includes a collapsible expansion cone (44, 46).

WO 2003/106130 A3

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

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International application No.
PCT/US03/18530

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : E21B 43/10
US CL : 166/207,217,382
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3,691,624 A (KINLEY) 19 September 1972 (19/09/1972), see especially Figure 1-3 and columns 3 and 4.	26, 29
A	US 3,631,926 A (YOUNG) 04 January 1972 (04/01/1972), see fig. 1.	30-33

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
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"P" document published prior to the international filing date but later than the priority date claimed
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"&" document member of the same patent family

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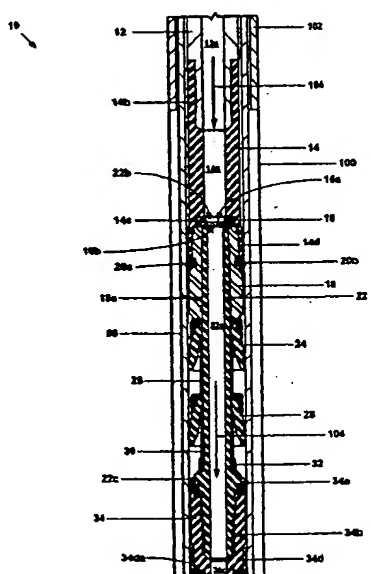
(54) Title: COLLAPSIBLE EXPANSION CONE



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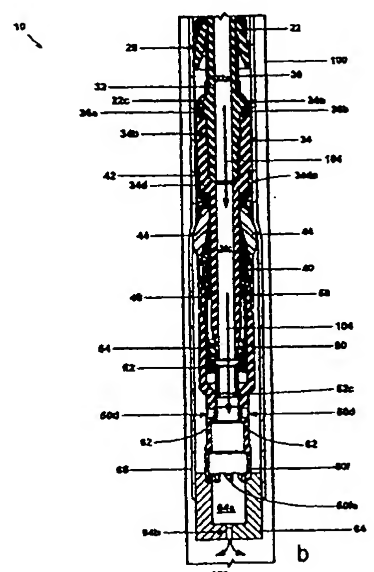

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(57) Abstract: An apparatus (910) for radially expanding and plastically deforming an expandable tubular member (66) includes a collapsible expansion cone (44, 46).

WO 2003/106130 A3

AMENDED CLAIMS

[received by the International Bureau on 20 August 2004 (20.08.04);
original claims 26, 29, 40 and 42 amended; claims 44-49 added,
remaining claims unchanged (6 pages)].

an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and

an outer portion defining arcuate cylindrical upper and lower surfaces;

wherein each upper expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion; and

wherein each lower expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion.

26. An apparatus for radially expanding and plastically deforming an expandable tubular member, comprising:

a tubular support member;

a collapsible expansion cone coupled to the tubular support member;

an expandable tubular member coupled to the collapsible expansion cone;

means for displacing the collapsible expansion cone relative to the expandable tubular member using fluid pressure; and

means for collapsing the expansion cone.

27. The apparatus of claim 26, wherein the tubular support member comprises an upper tubular support member comprising an internal flange and a lower tubular support member comprising an internal flange; wherein the expansion cone comprises:

an upper cam assembly coupled to the upper tubular support member comprising:

a tubular base coupled to the upper support member; and

a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface;

a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the internal flange of the upper tubular support member;

a lower cam assembly coupled to the lower tubular support member comprising:

a tubular base coupled to the lower tubular support member; and

a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments;

wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly; and

a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the internal flange

of the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly; and wherein the apparatus further comprises:

means for releasably coupling the upper tubular support member to the lower tubular support member; and

means for limiting movement of the upper tubular support member relative to the lower tubular support member.

28. The apparatus of claim 26, further comprising:

means for pivoting the upper expansion cone segments; and

means for pivoting the lower expansion cone segments.

29. The apparatus of claim 26, further comprising:

means for pulling the collapsible expansion cone through the expandable tubular member using fluid pressure.

30. A collapsible expansion cone, comprising:

an upper cam assembly comprising:

a tubular base; and

a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface;

a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly;

a lower cam assembly comprising:

a tubular base; and

a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments;

wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly;

a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly;

means for moving the upper cam assembly away from the lower expansion cone segments; and

means for moving the lower cam assembly away from the upper expansion cone segments.

31. The apparatus of claim 30, wherein the upper and lower expansion cone segments together define an arcuate spherical external surface.

32. The apparatus of claim 30, wherein each upper expansion cone segment comprises:
an inner portion defining an arcuate cylindrical upper surface and arcuate cylindrical lower surfaces;
an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and
an outer portion defining arcuate cylindrical upper and lower surfaces; and
wherein each lower expansion cone segment comprises:
an inner portion defining an arcuate cylindrical upper surface and arcuate cylindrical lower surfaces;
an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface; and
an outer portion defining arcuate cylindrical upper and lower surfaces.

33. The apparatus of claim 30, wherein each upper expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion; and
wherein each lower expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion.

34. A packer cup apparatus comprising:
a central mandrel,
a sealing cup comprising
a substantially unrestricted lip for sealing engaging a tubular member, and
a base portion for sealingly engaging the central mandrel,
a protecting member positioned longitudinally along the central mandrel,
a pliant backup member positioned between the protecting member and the sealing cup,
a conical bushing positioned partially between the sealing cup and the central mandrel for supporting the base portion of the sealing cup.

35. The apparatus of claim 34 wherein the pliant backup member is made from a material selected from the group consisting of fluropolymer, fluoroelastomer, Telflon, or PEEK.

36. The apparatus of claim 34 further comprising a restraining member surrounding the base portion of the sealing cup for restraining the sealing cup.

AMENDED SHEET (ARTICLE 19)

37. The apparatus of claim 34 wherein the protecting member is a thimble surrounding the base portion of the sealing cup.

38. The apparatus of claim 37 wherein the sealing cup further comprises an unsupported portion between the thimble and a point of engagement with the expandable tubular member, and a means for reducing the unsupported portion of the sealing cup.

39. A method of radially expanding and plastically deforming an expandable tubular member, comprising:

supporting the expandable tubular member using a tubular support member and a collapsible expansion cone;

injecting a fluidic material into the tubular support member;

sensing the operating pressure of the injected fluidic material within a first interior portion of the tubular support member;

displacing the collapsible expansion cone relative to the expandable tubular member when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the first interior portion of the tubular support member;

sensing the operating pressure of the injected fluidic material within a second interior portion of the tubular support member; and

collapsing the collapsible expansion cone when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the second interior portion of the tubular support member.

40. The method of claim 39, further comprising:

pulling the collapsible expansion cone through the expandable tubular member when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the first interior portion of the tubular support member.

41. The method of claim 40, wherein pulling the collapsible expansion cone through the expandable tubular member comprises:

coupling one or more cup seals to the tubular support member above the collapsible expansion cone;

pressuring the interior of the expandable tubular member below the cup seals; and

pulling the collapsible expansion cone through the expandable tubular member using the cup seals.

42. The method of claim 39, wherein the tubular support member comprises an upper tubular support member and a lower tubular support member; and wherein collapsing the collapsible expansion cone comprises displacing the upper tubular member relative to the lower tubular support member.

43. The method of claim 42, wherein the collapsible expansion cone comprises:
an upper cam assembly comprising:
a tubular base; and
a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface;
a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the upper tubular support member;
a lower cam assembly comprising:
a tubular base; and
a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments;
wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly; and
a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly.

44. An apparatus for radially expanding and plastically deforming an expandable tubular member, comprising:
a tubular support member;
a collapsible expansion device coupled to the tubular support member;
an expandable tubular member coupled to the collapsible expansion cone;
means for displacing the collapsible expansion device relative to the expandable tubular member using fluid pressure; and
means for collapsing the expansion cone.

45. The apparatus of claim 44, further comprising:
means for pulling the collapsible expansion device through the expandable tubular member using fluid pressure.

46. A method of radially expanding and plastically deforming an expandable tubular member, comprising:

supporting the expandable tubular member using a tubular support member and a collapsible expansion device;

injecting a fluidic material into the tubular support member;

sensing the operating pressure of the injected fluidic material within a first interior portion of the tubular support member;

displacing the collapsible expansion device relative to the expandable tubular member when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the first interior portion of the tubular support member;

sensing the operating pressure of the injected fluidic material within a second interior portion of the tubular support member; and

collapsing the collapsible expansion device when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the second interior portion of the tubular support member.

47. The method of claim 46, further comprising:

pulling the collapsible expansion device through the expandable tubular member when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the first interior portion of the tubular support member.

48. The method of claim 47, wherein pulling the collapsible expansion device through the expandable tubular member comprises:

coupling one or more cup seals to the tubular support member above the collapsible expansion device;

pressuring the interior of the expandable tubular member below the cup seals; and

pulling the collapsible expansion device through the expandable tubular member using the cup seals.

49. The method of claim 46, wherein the tubular support member comprises an upper tubular support member and a lower tubular support member; and wherein collapsing the collapsible expansion device comprises displacing the upper tubular member relative to the lower tubular support member.

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E21B 43/10

(52) UK CL (Edition X):
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WO 2002/059456 A
US 3785193 A
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UK CL (Edition X) **E1F**
INT CL7 **E21B**
Other: **Online: WPI, EPODOC, JAPIO**

(54) Abstract Title: **Adjustable expansion cone assembly**

(57) Apparatus 200 for radially expanding a tubular member 120 comprises a tubular support member 205, expansion cone segments 225 and a tapered cone body 215g for increasing the outside diameter of the expansion cone segments. The expansion cone segments 225 are driven up the tapered portion 215g either by frictional forces exerted by drag blocks 235 and 255 on the expandable tubular member 120 or by the engagement of a resilient collet or resilient dogs with the lower end of the expandable tubular member 120. Packer cup assemblies 240 and 250 seal off an annular region between the expandable tubular member 120 and the tubular support member 215. The tubular support member 205 is locked to the tapered cone body 215g during insertion of the apparatus 200 into the tubular member 120. After moving the cone segments 225 and cone body 215g out of the far end of the tubular member, they are reinserted into the tubular member and the cone body 215g is unlocked from the tubular support member 205.

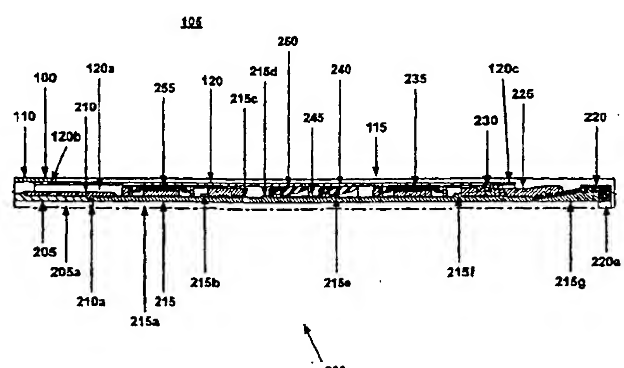

Fig. 1

GB 2 406 117 A

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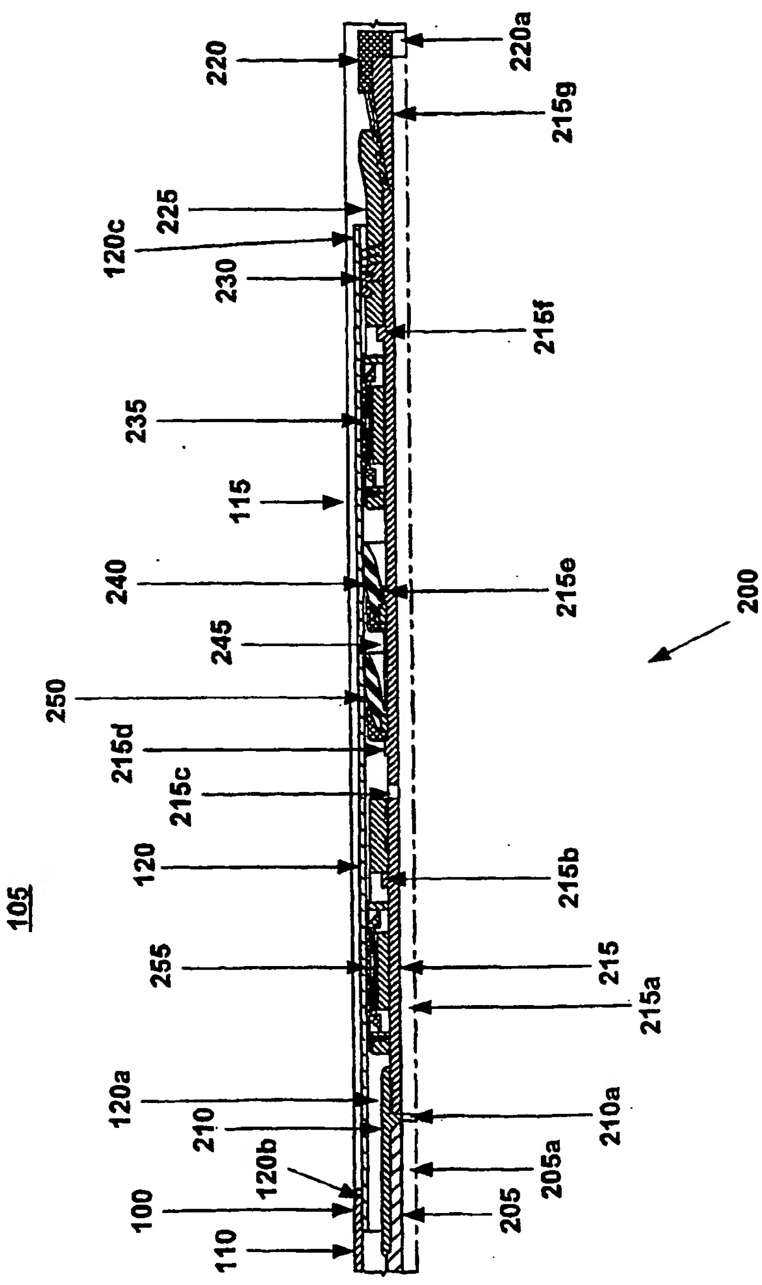
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Fig. 1

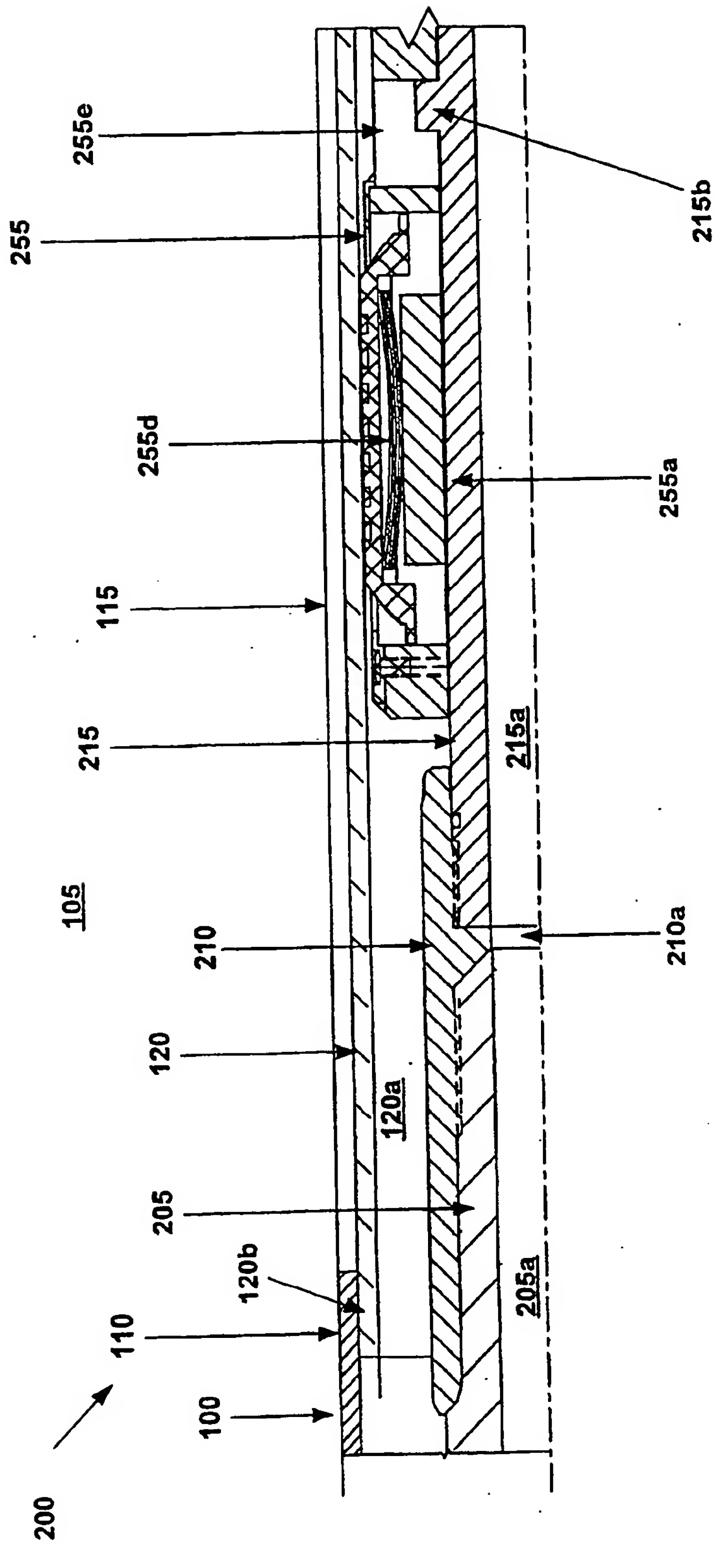
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Fig. 1a

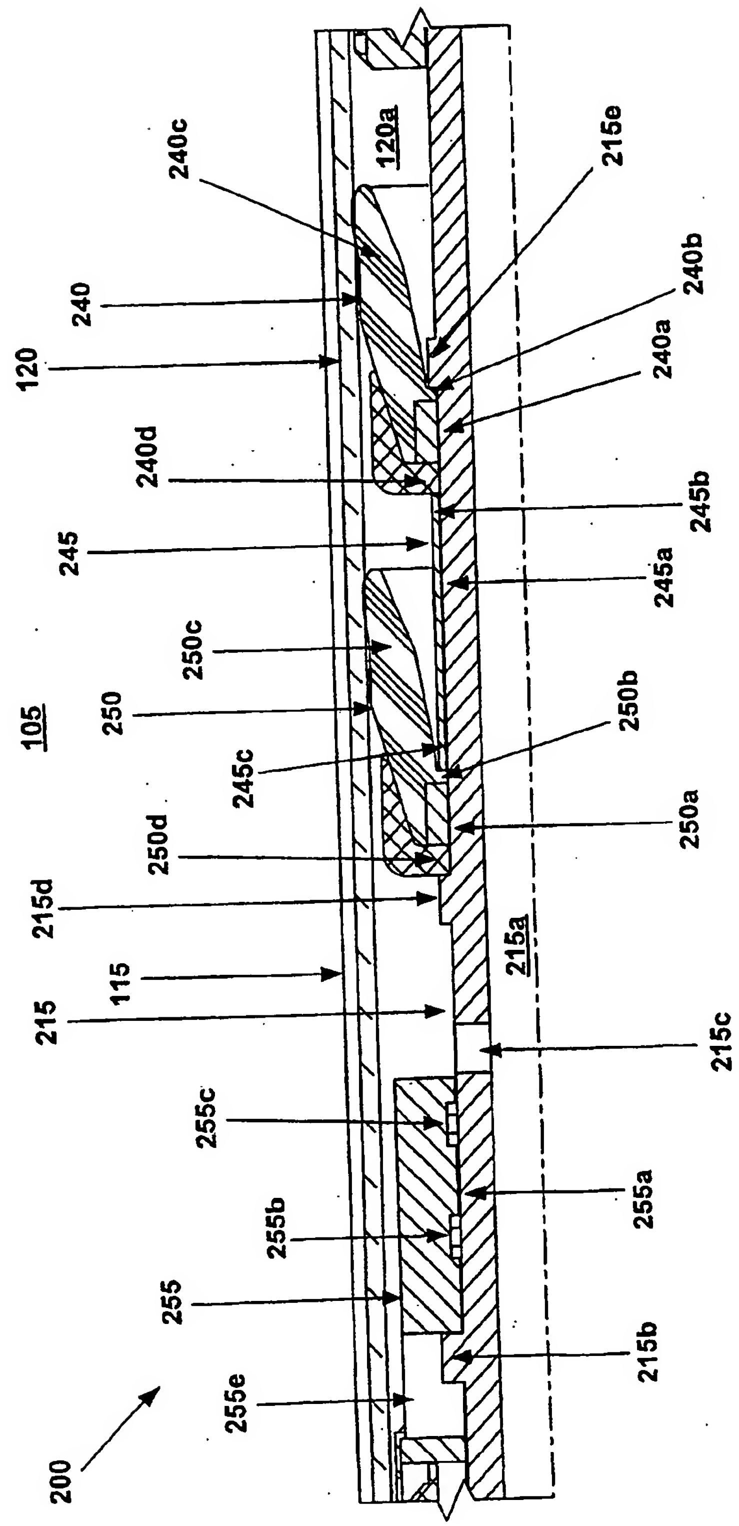

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Fig. 1b

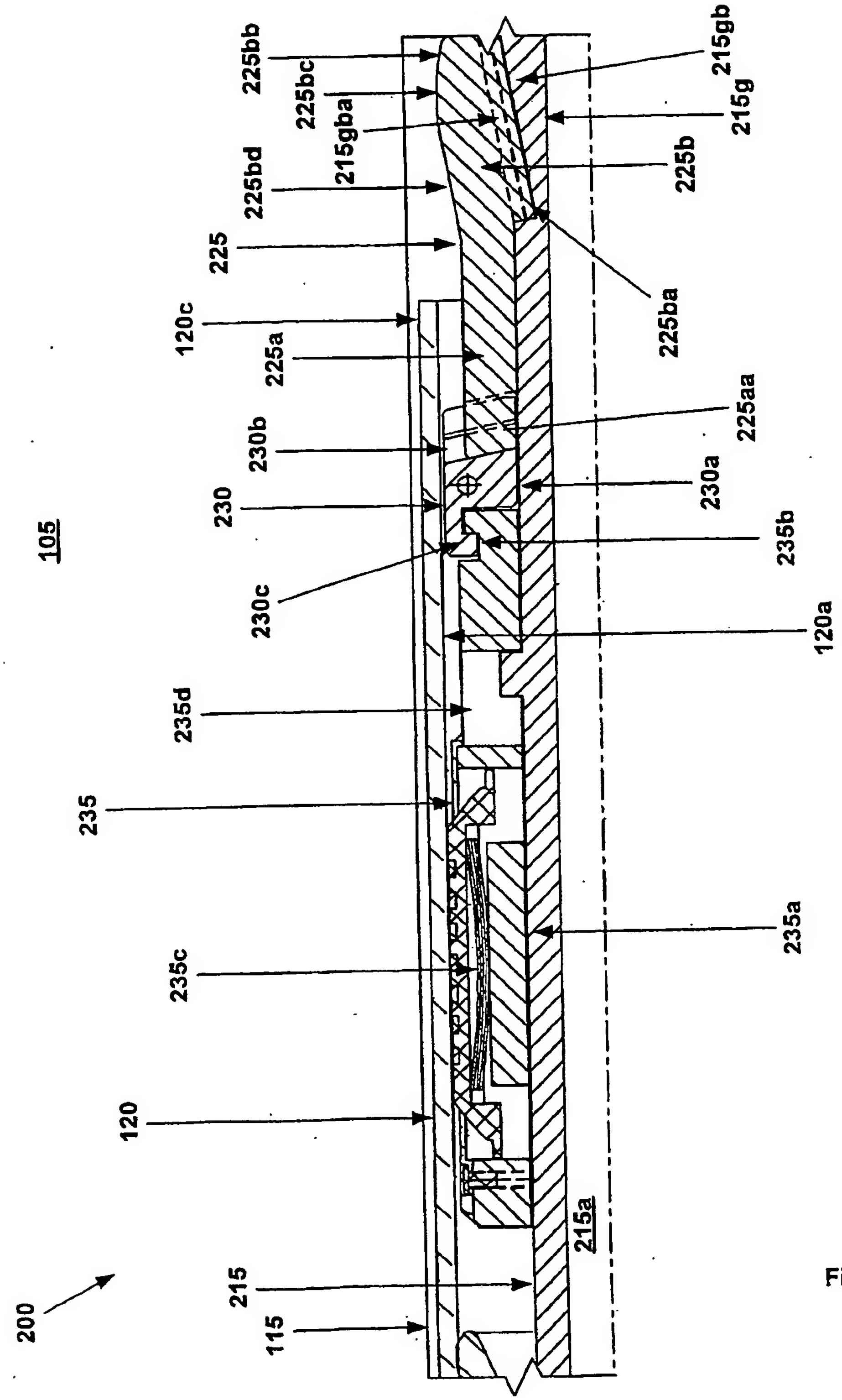

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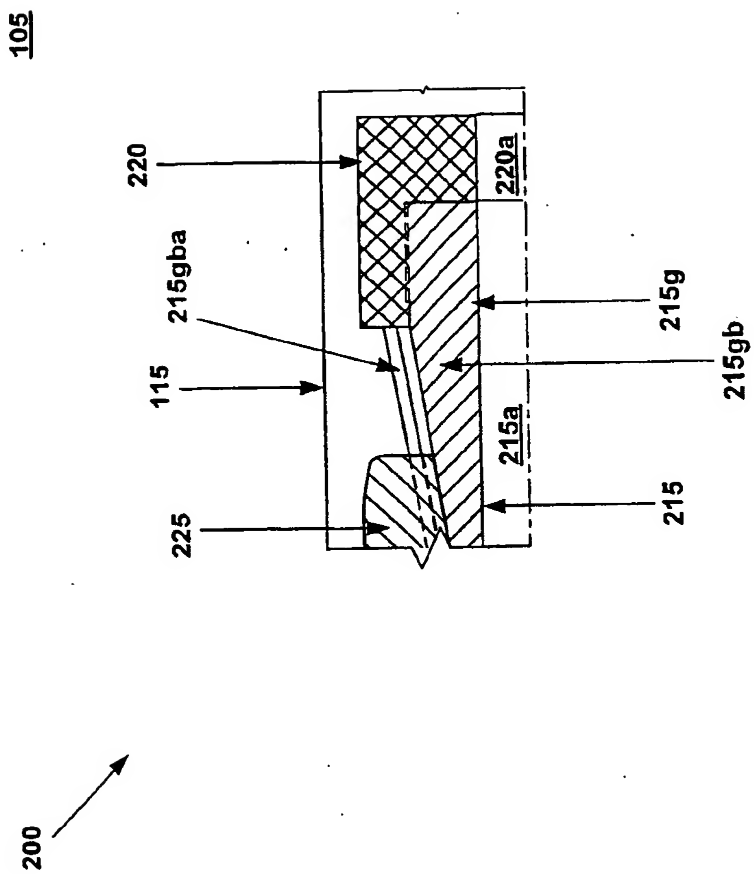
Fig. 1c



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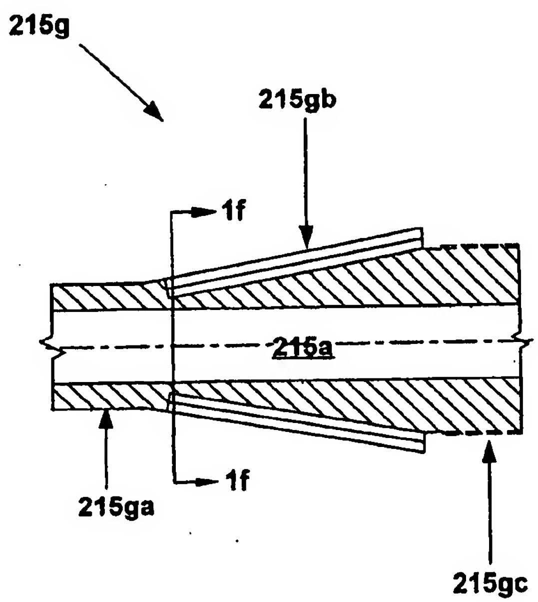
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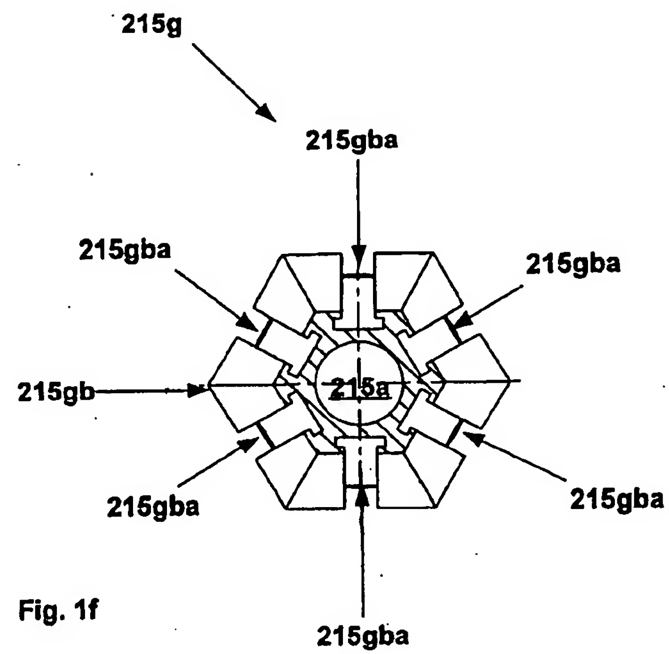
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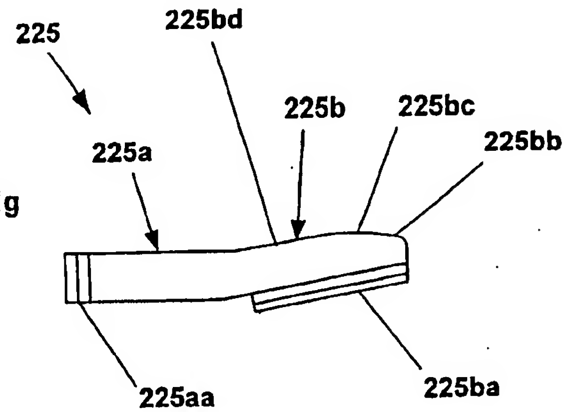
Fig. 1f

Fig. 1g



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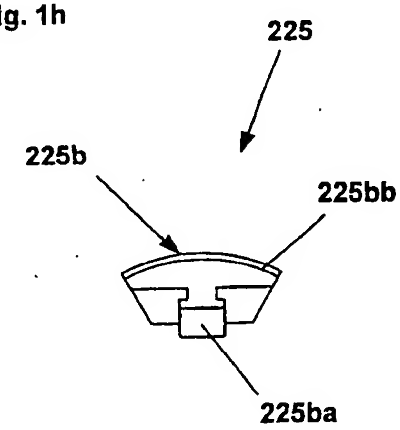
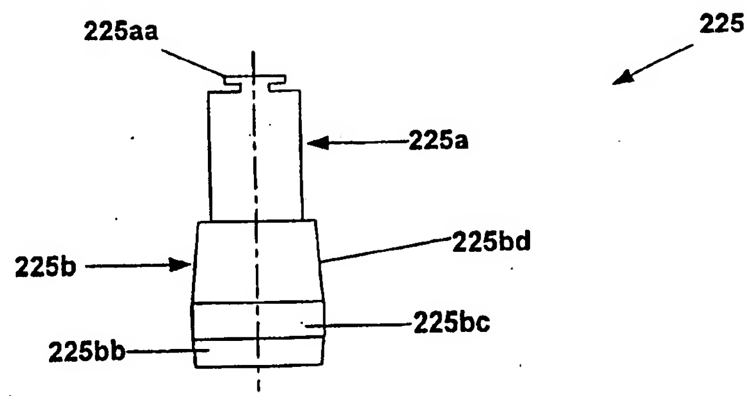


Fig. 1i



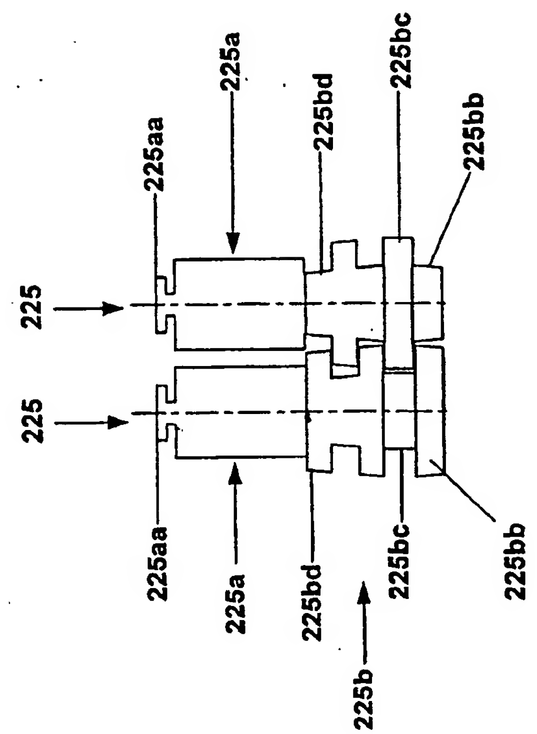

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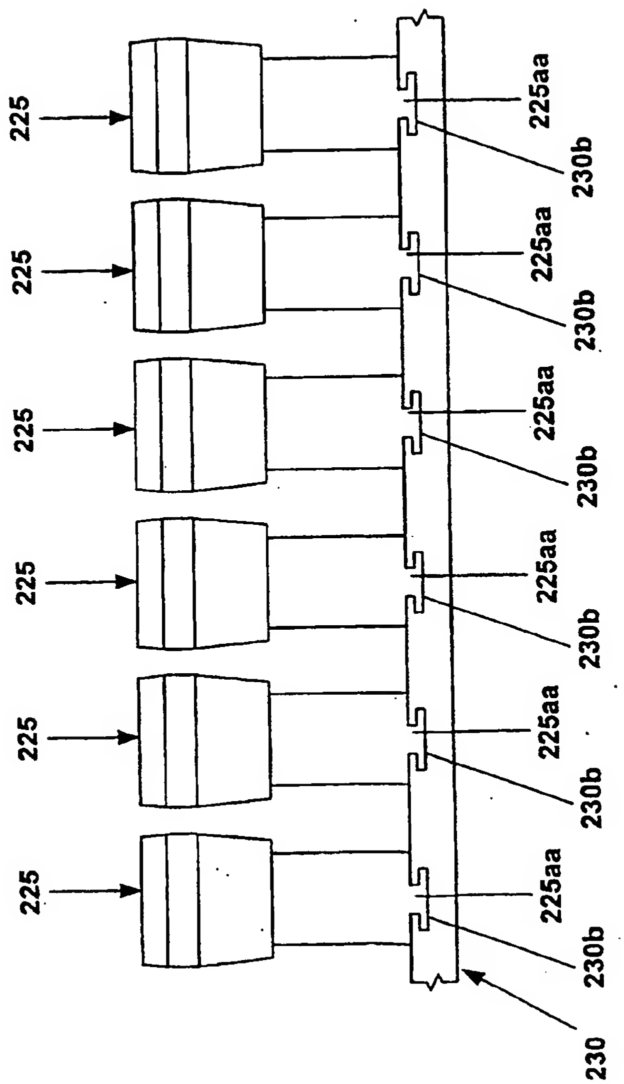
Fig. 1j



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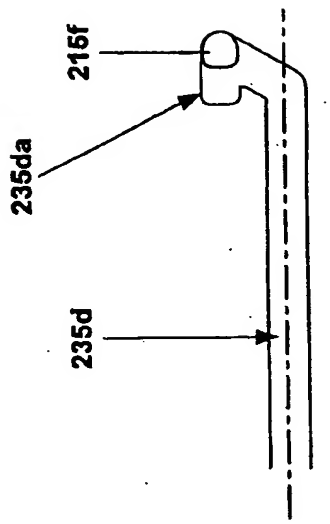

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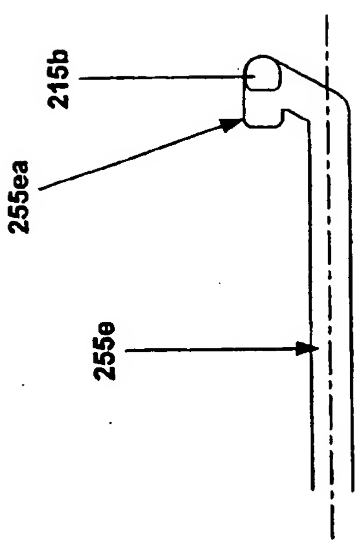
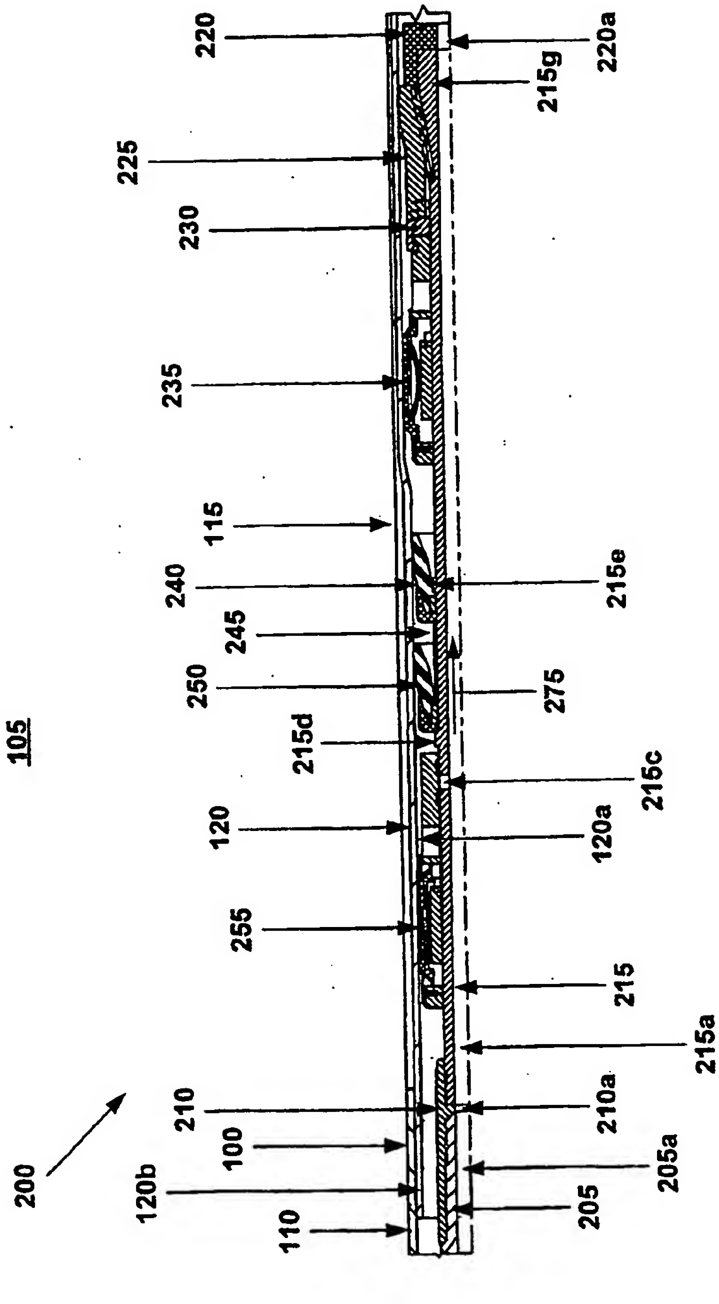


Fig. 1l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240
215e
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215c
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215
215a
210
210a
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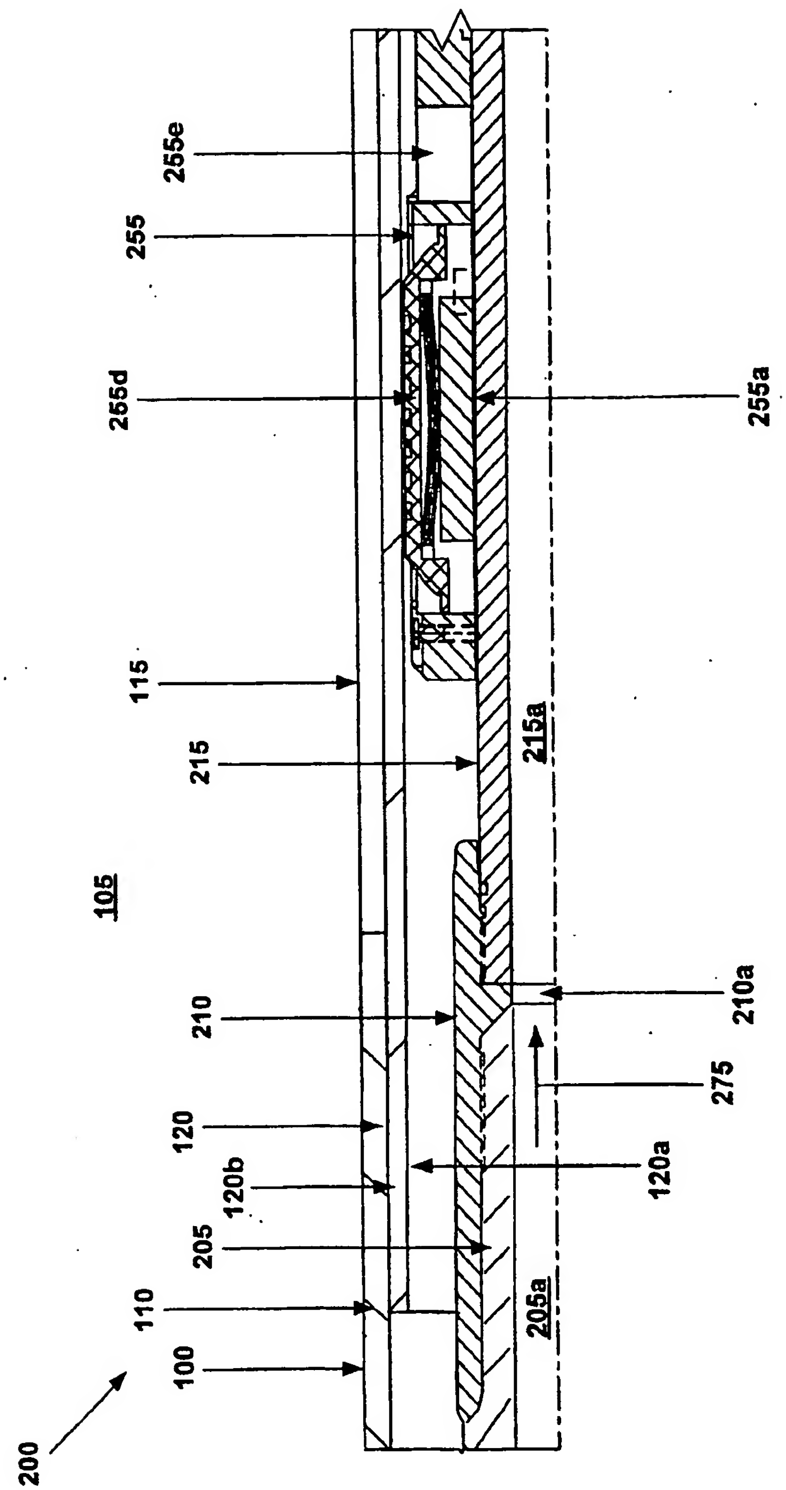
120b
205a
110
205

Fig. 2



200
100
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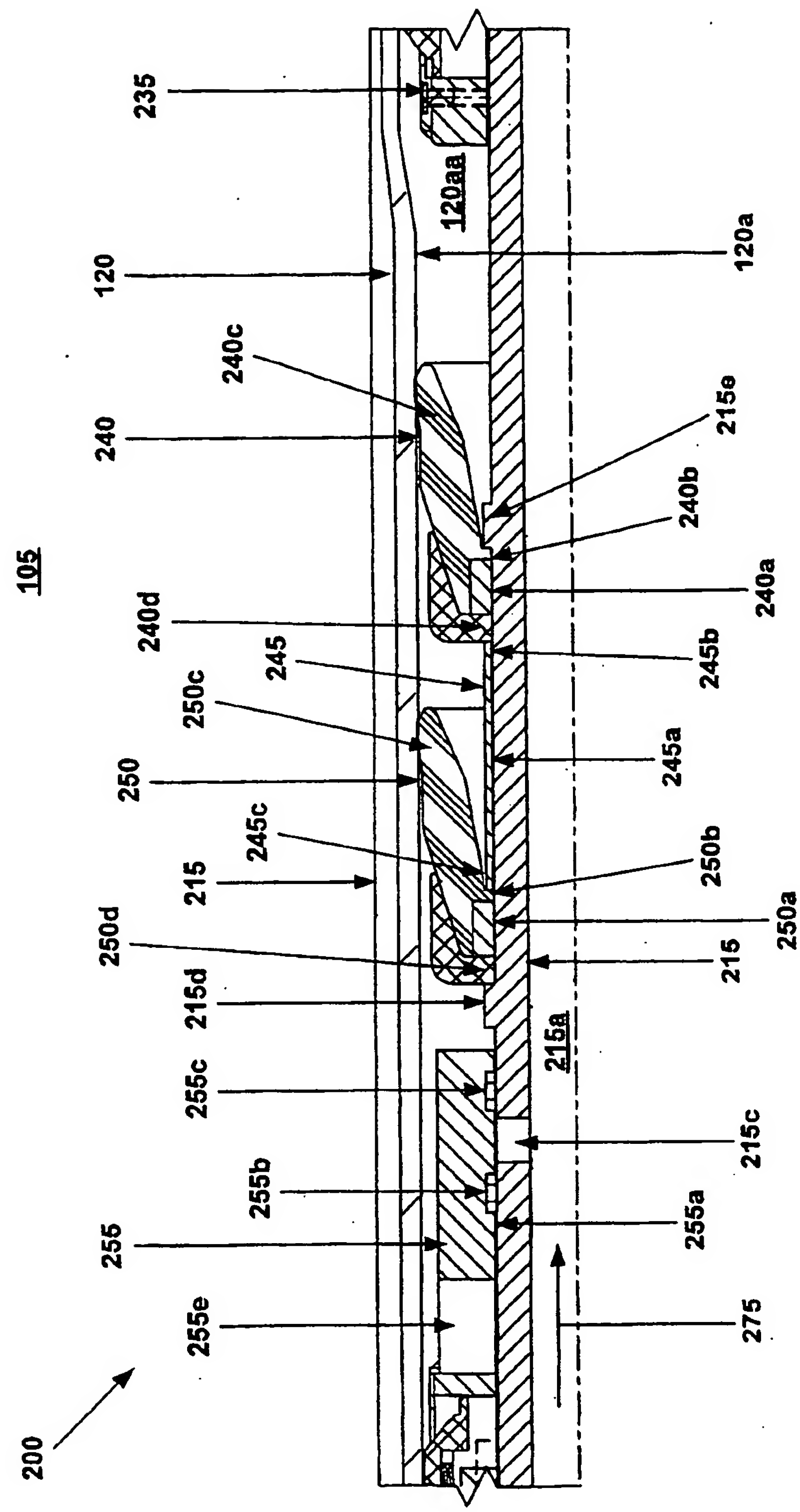
255e
205a
120a
275
210a
215a
255a

Fig. 2a



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255c
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250c
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240
240c
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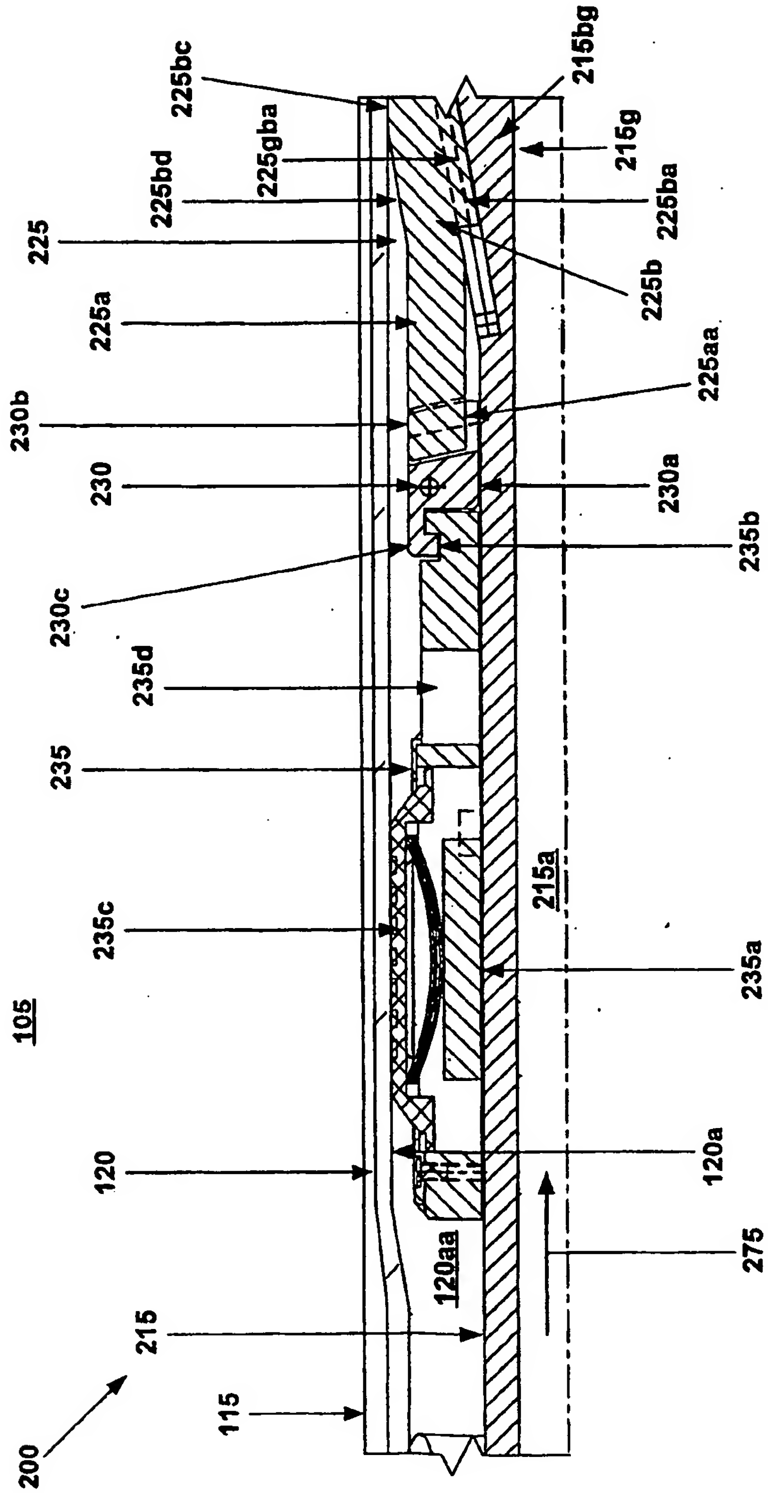
250a
215
215a
215c
255a
275

Fig. 2b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225b
225bd
225ba
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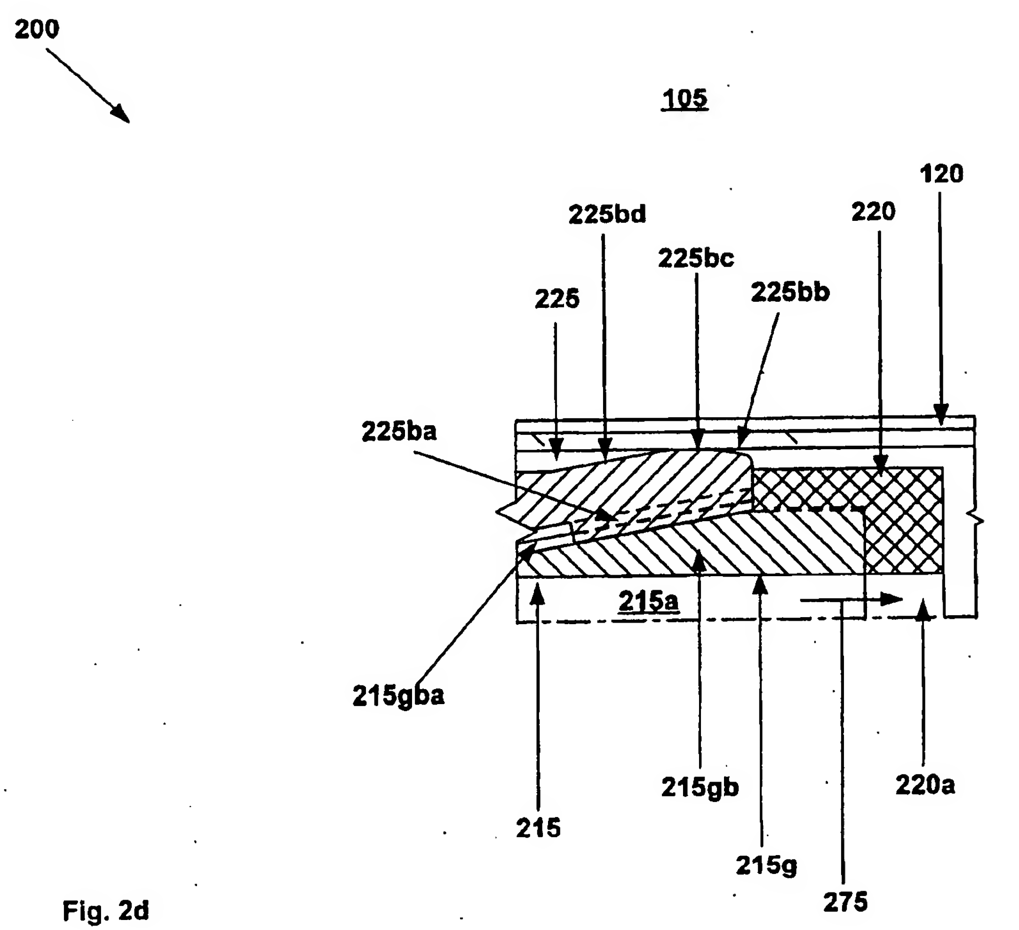
215g
225bc
215bg

Fig. 2c



200
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225bb
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225ba
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215gba
215gb
220a
215
215g
275

Fig. 2d

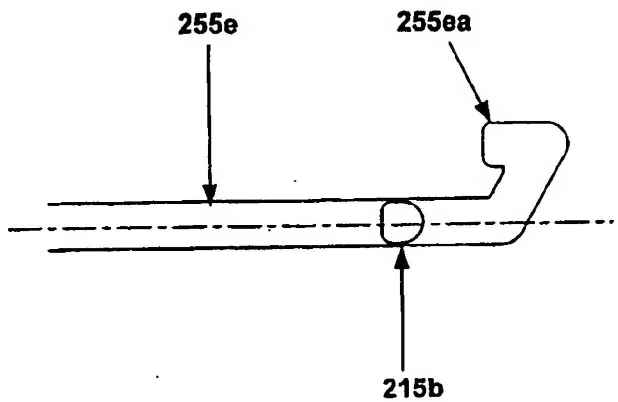


Fig. 2e

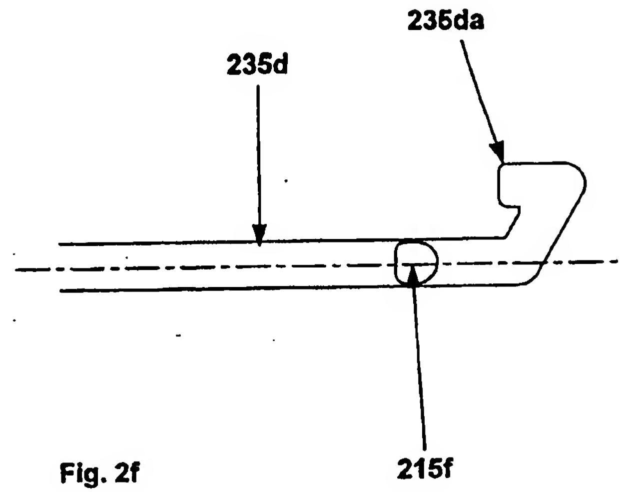


Fig. 2f

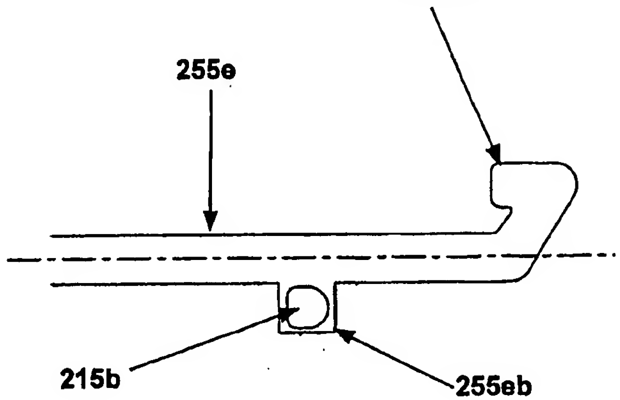


Fig. 2g

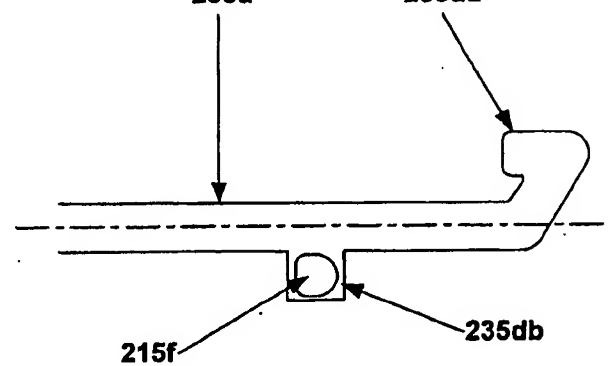
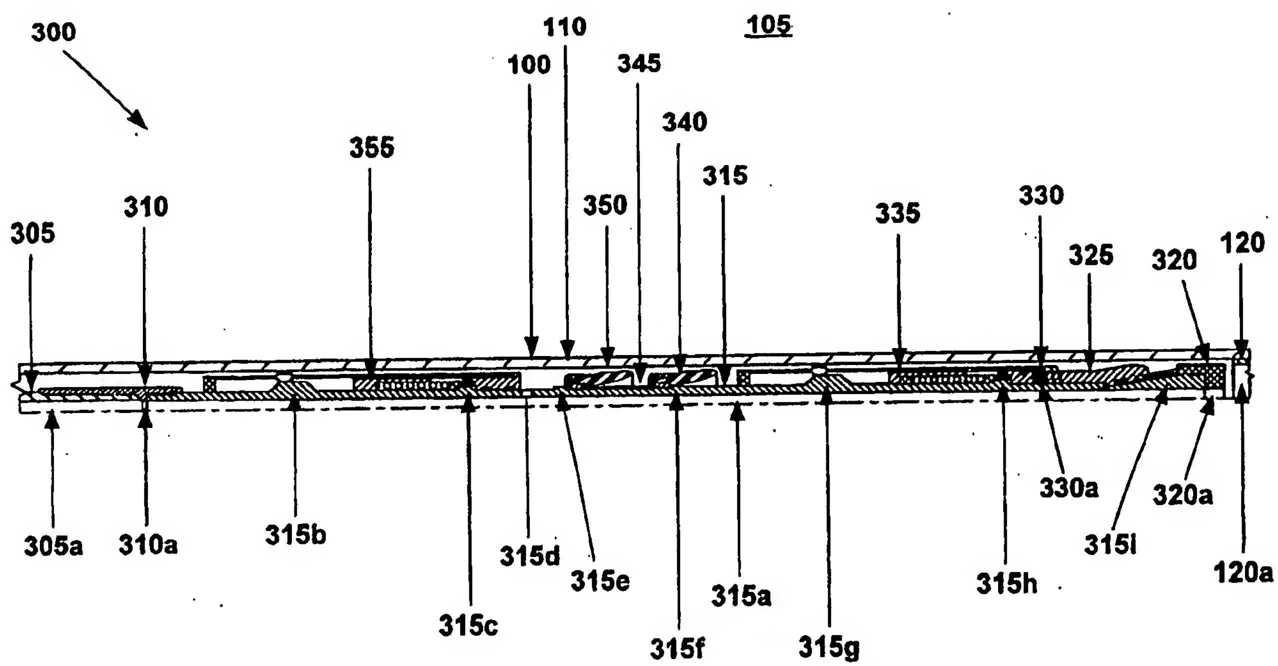


Fig. 2h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315f
315g
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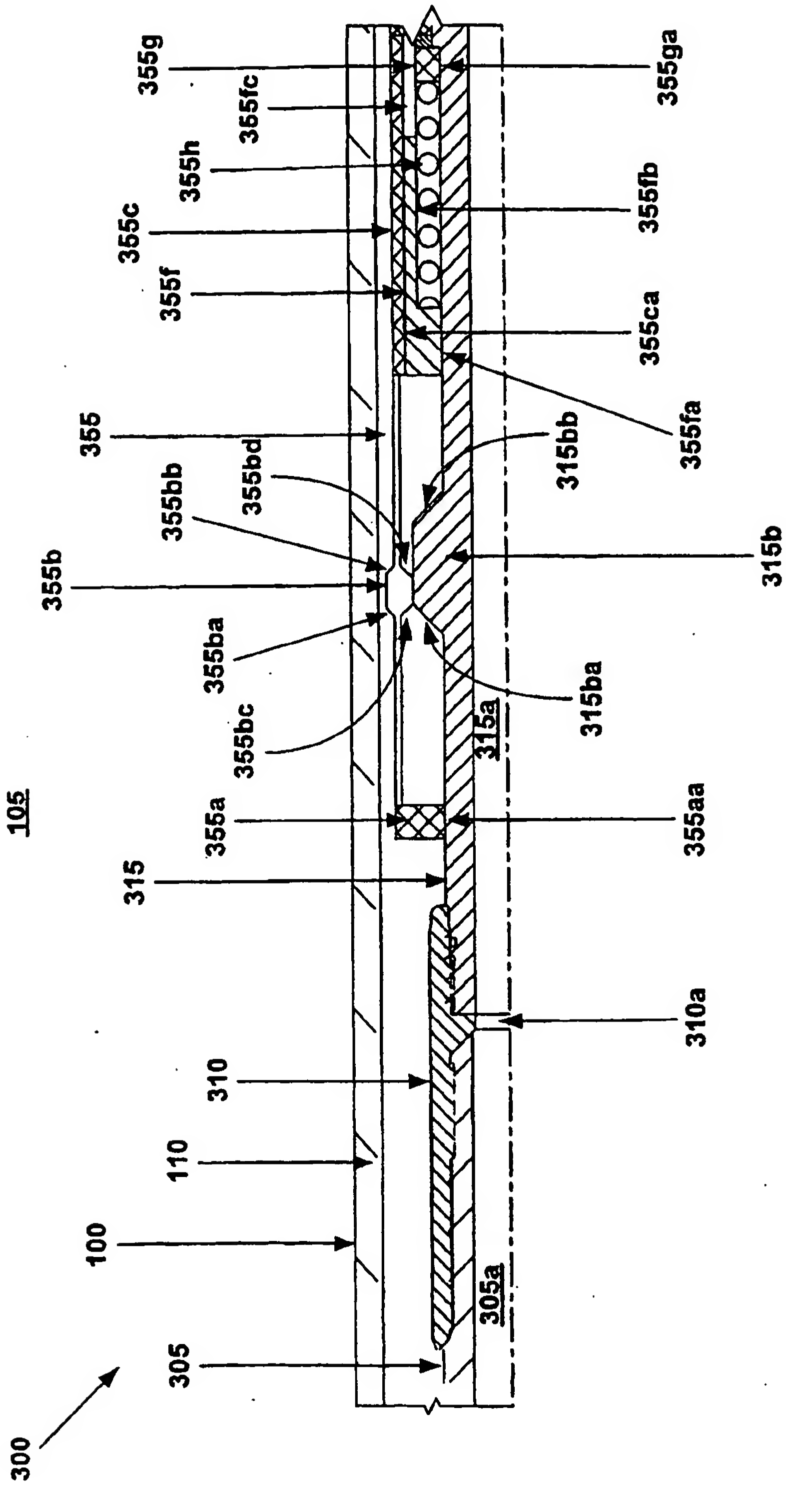
320a
315l
315h
120a

Fig. 3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355bb
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355f
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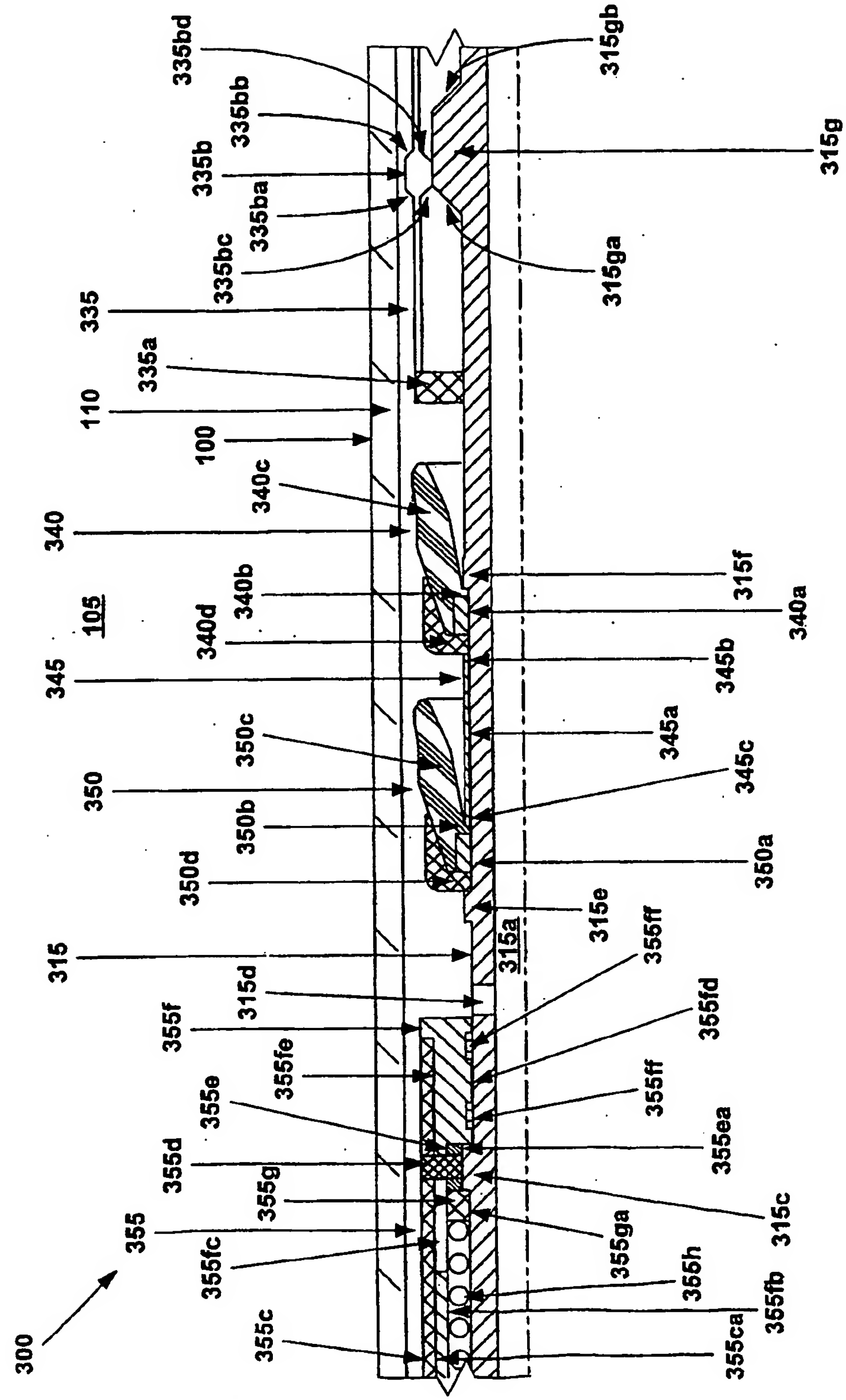
355ga

Fig. 3a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335bb
335bd
315gb
315g
315ga
315f
340a
345b
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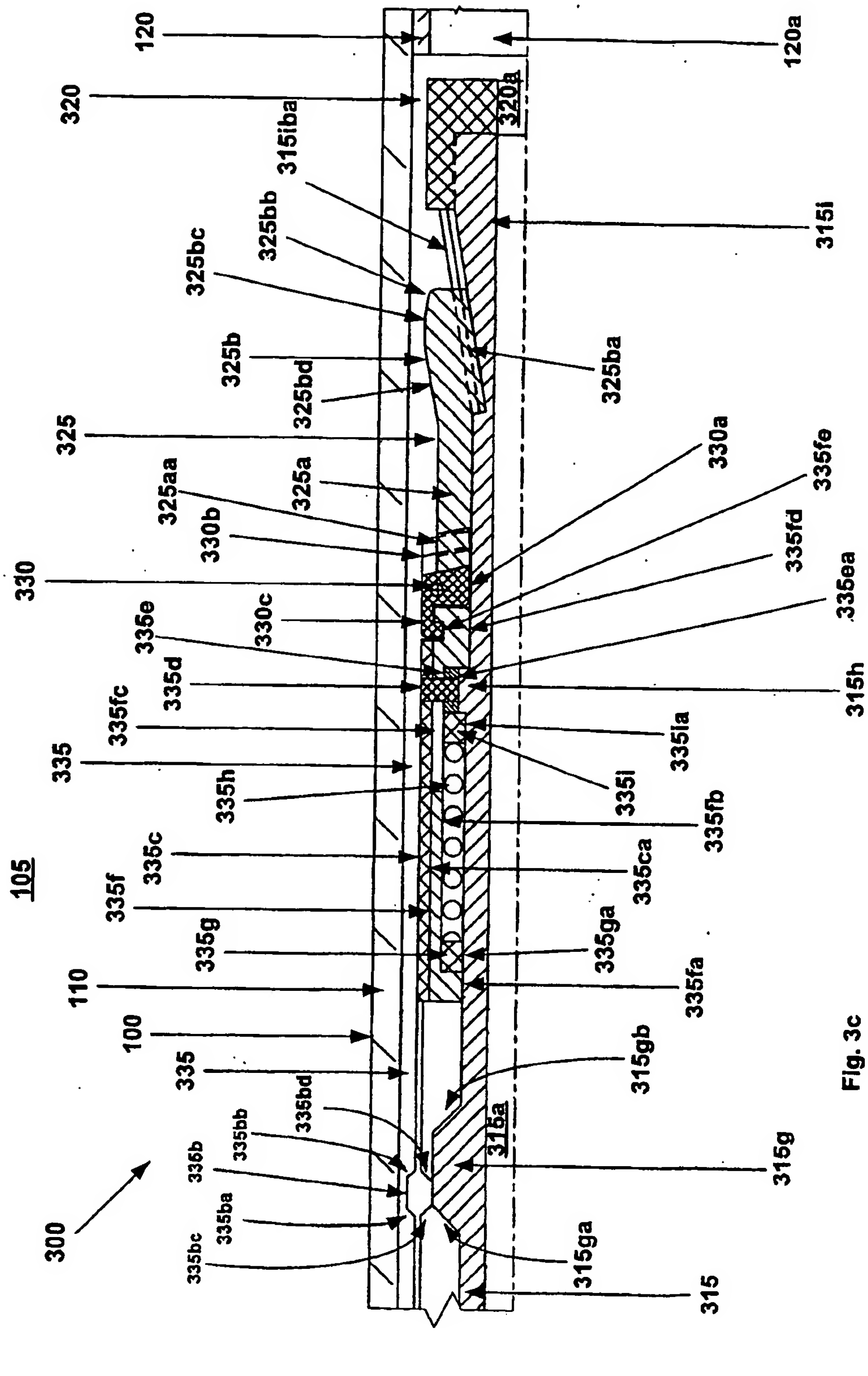
355ca

Fig. 3b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330a
330b
335fe
330
335fd
330c
335ea
335e
335d
315h
335fc
335la
335
335i
335h
335fb
335c
335ca
335f
335g
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335
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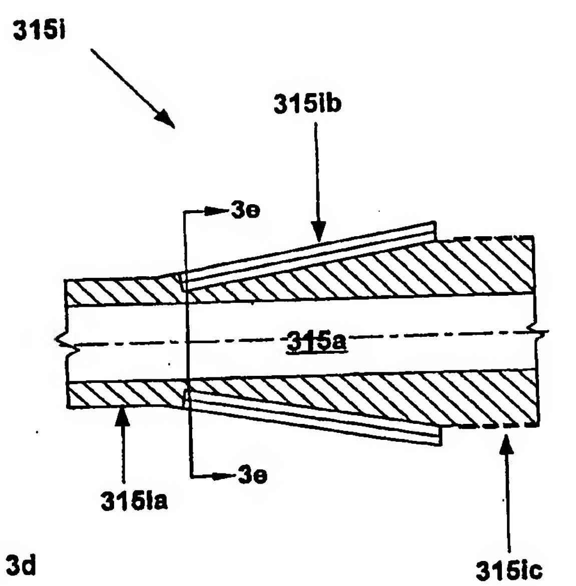
315g
335ba
315ga
335bc
315

Fig. 3c



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315ib
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3e
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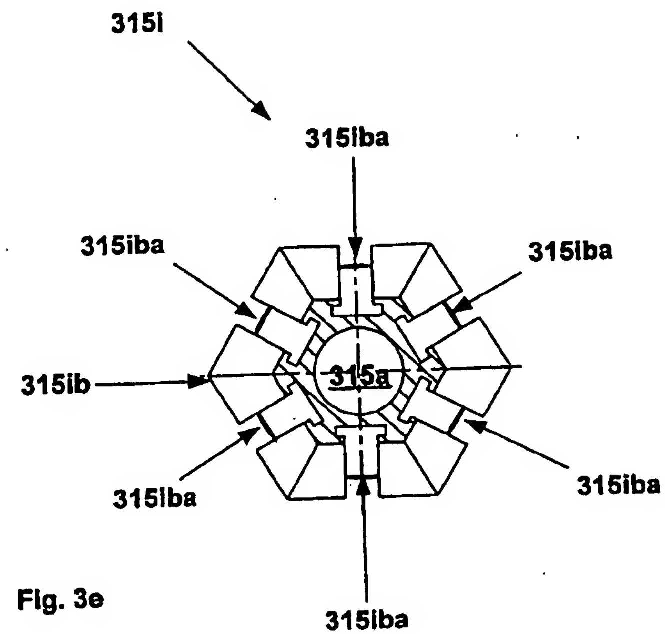
315ia
315ic

Fig. 3d



315i
315iba
315iba
315iba
315ib
315a
315iba
315iba
315iba

Fig. 3e

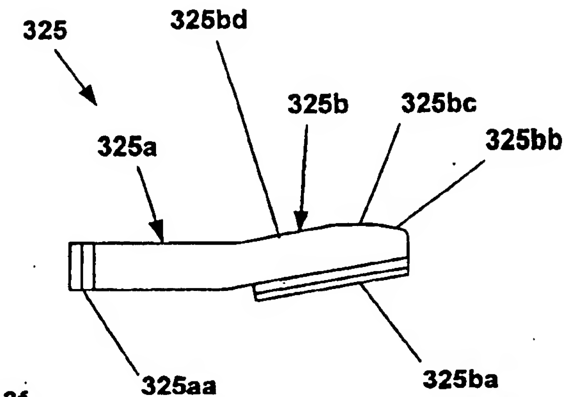


Fig. 3f

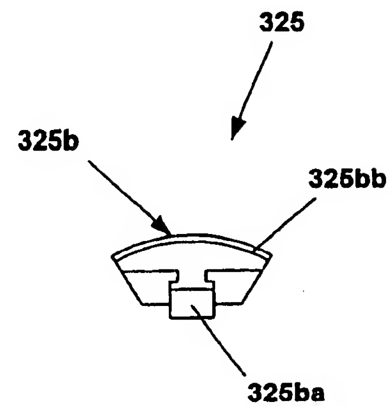


Fig. 3g

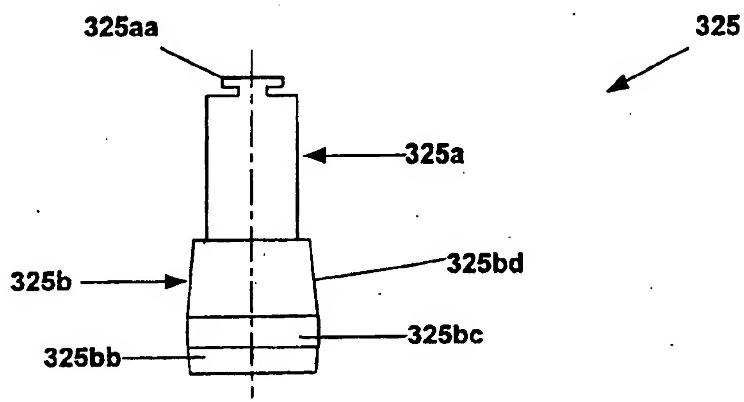
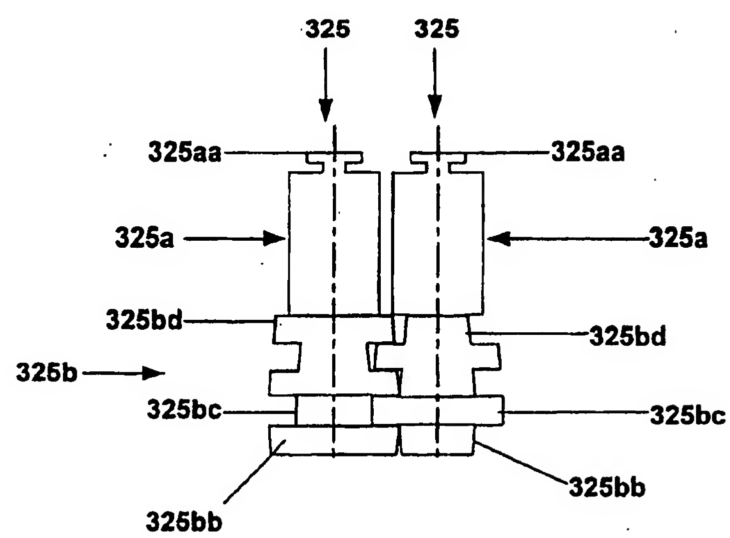


Fig. 3h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325bc
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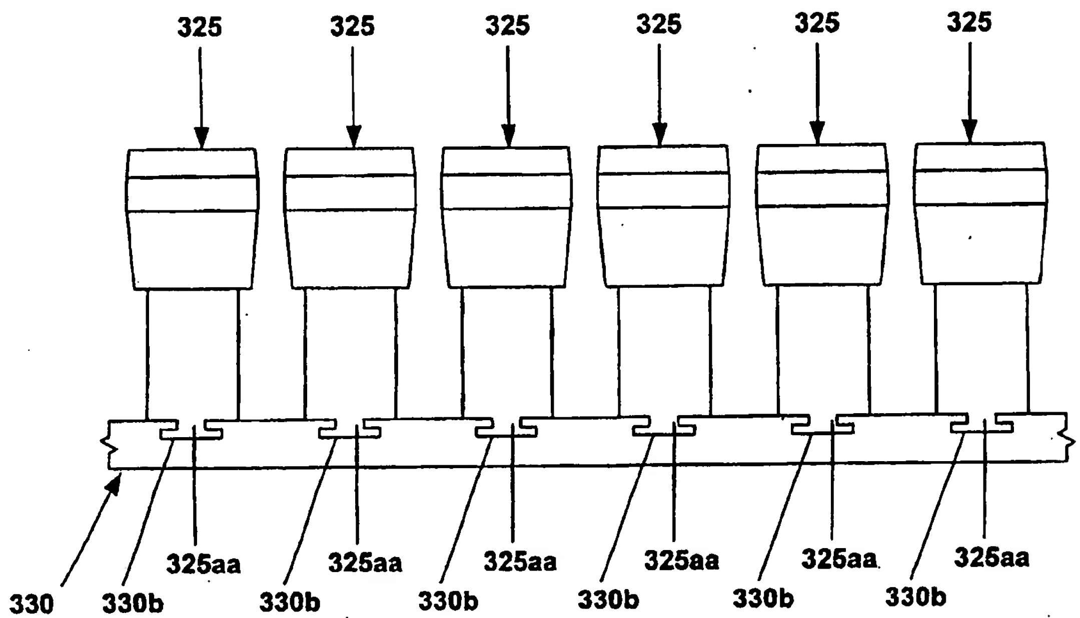
325bb
325bb

Fig. 3I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325
325
325
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325aa
325aa
325aa
325aa
325aa
325aa
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330b
330b
330b
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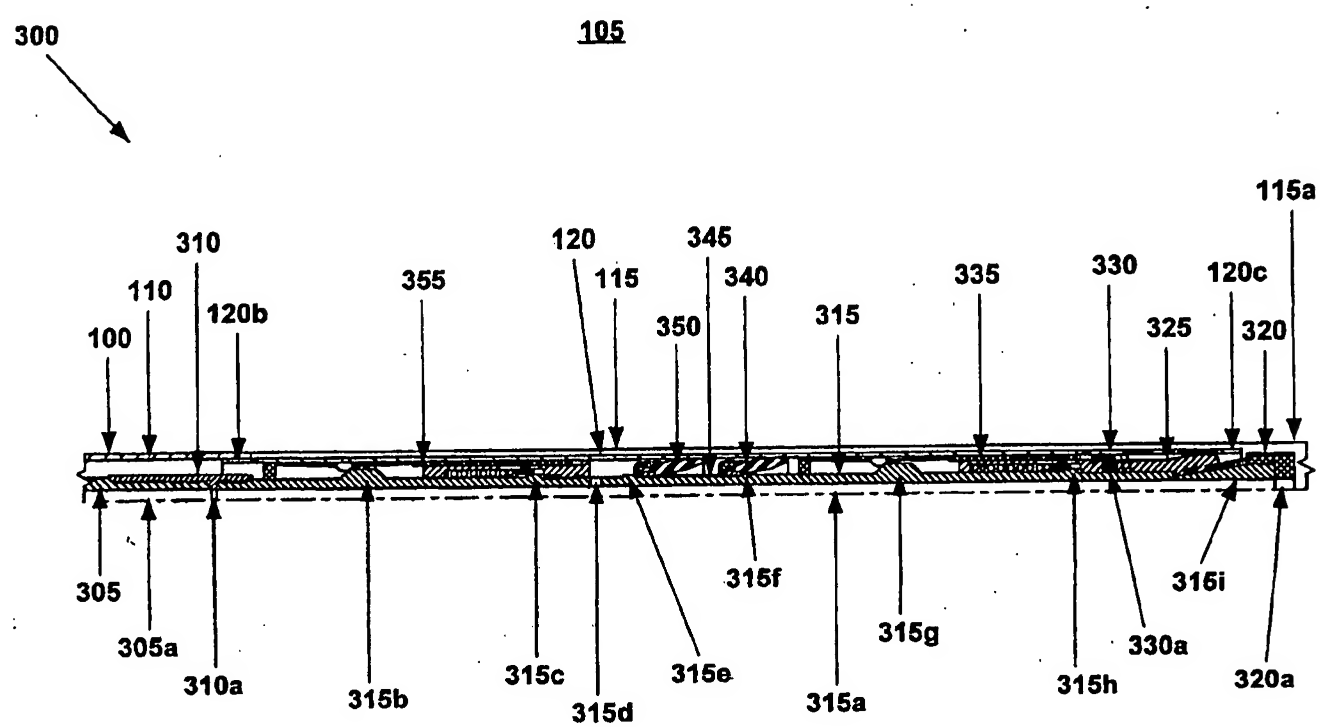
330b
330b

Fig. 3j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120b
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100
325
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315e
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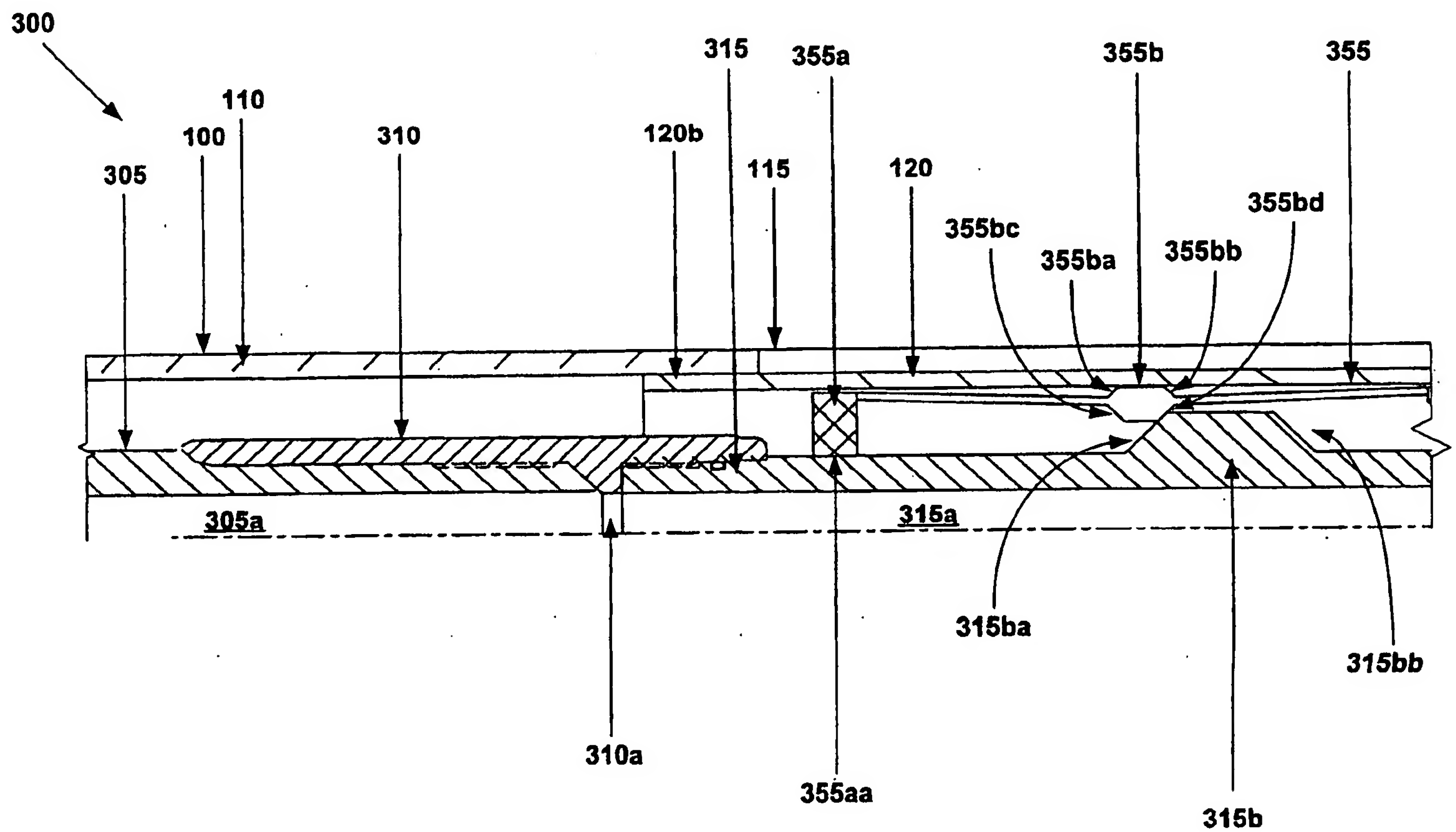
315g
315h
330a
316i
320a

Fig. 4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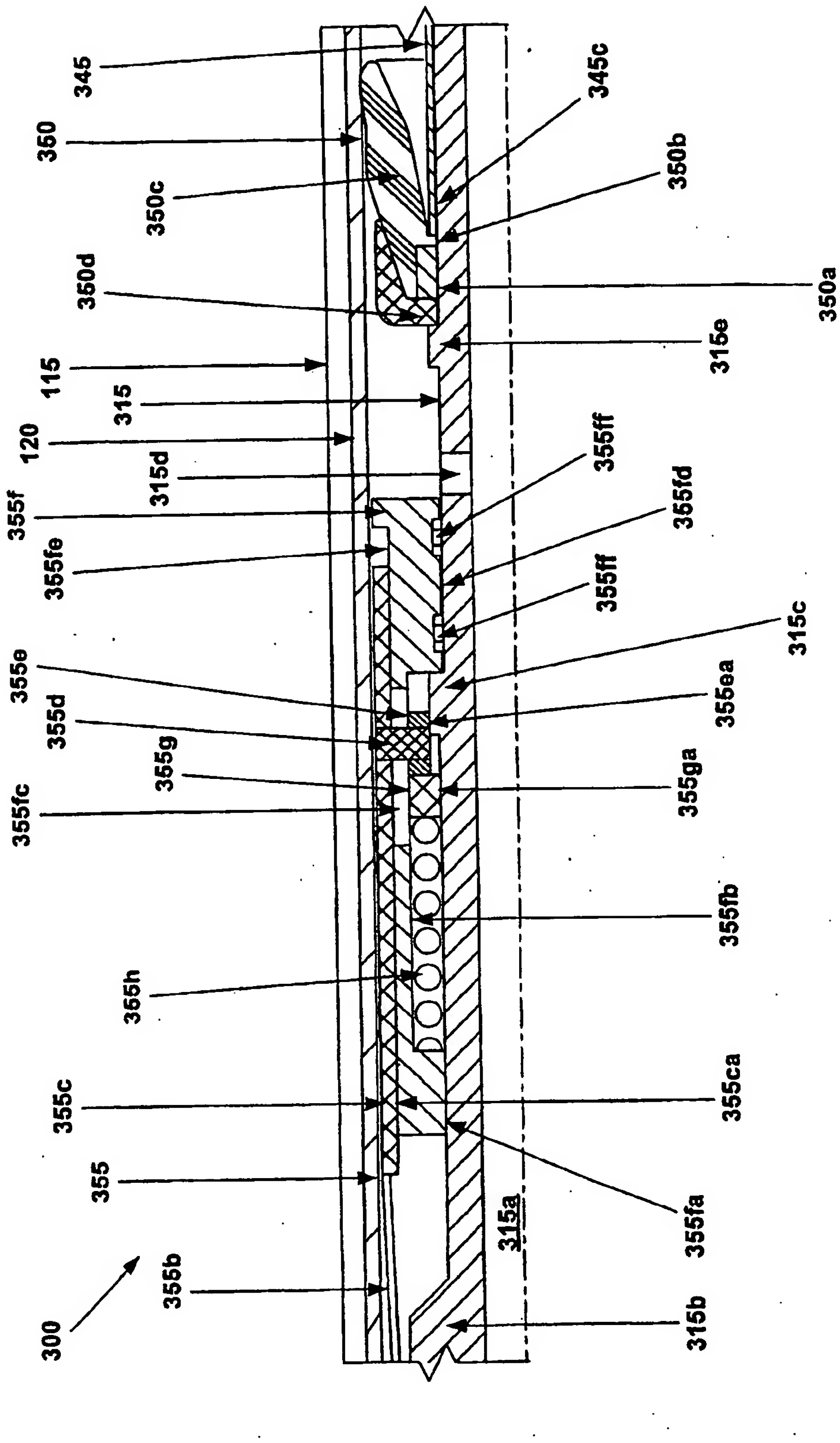
315b

Fig. 4a



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355b
345c
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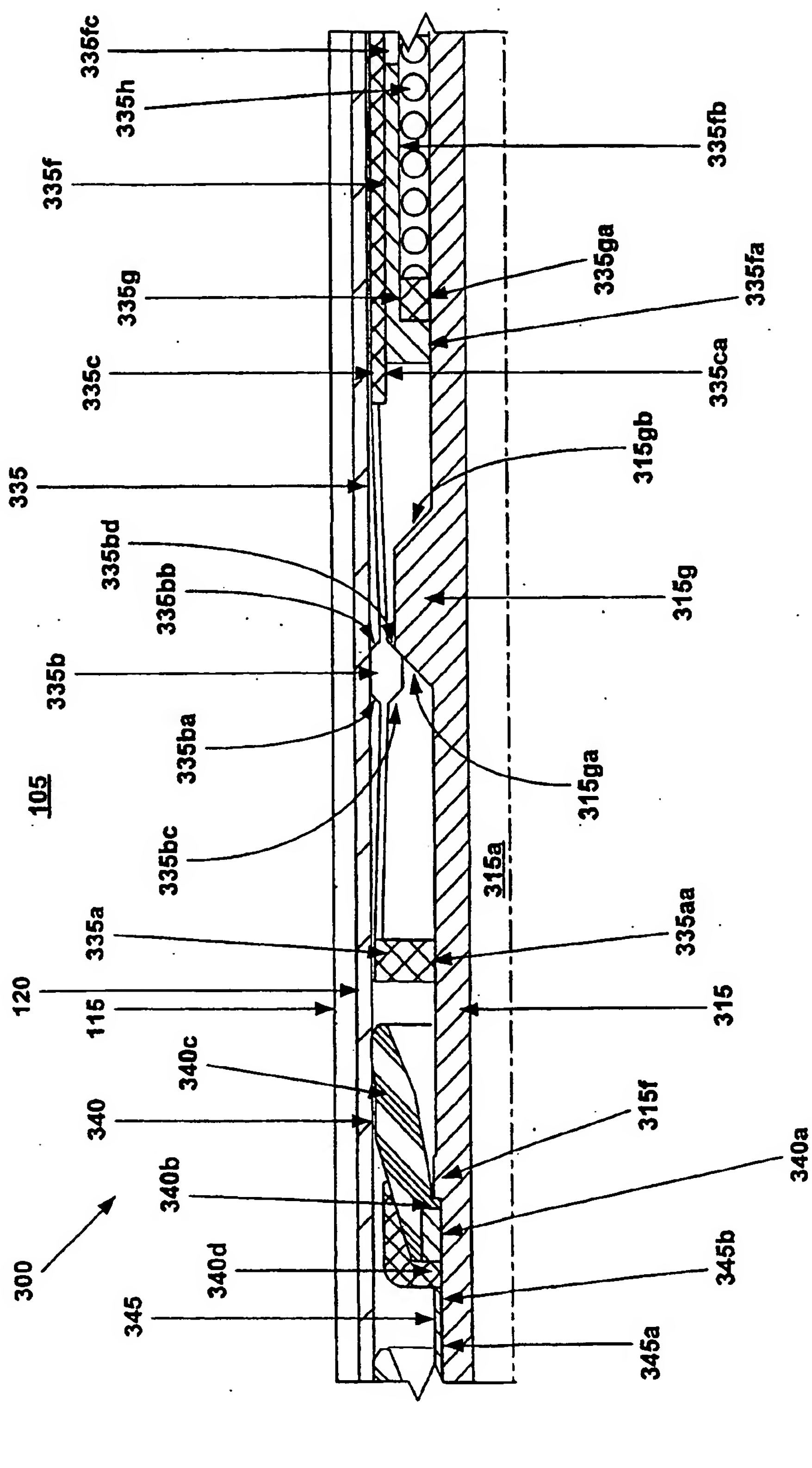
355fa
315a
315b

Fig. 4b



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335h
335fc
105
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335fb
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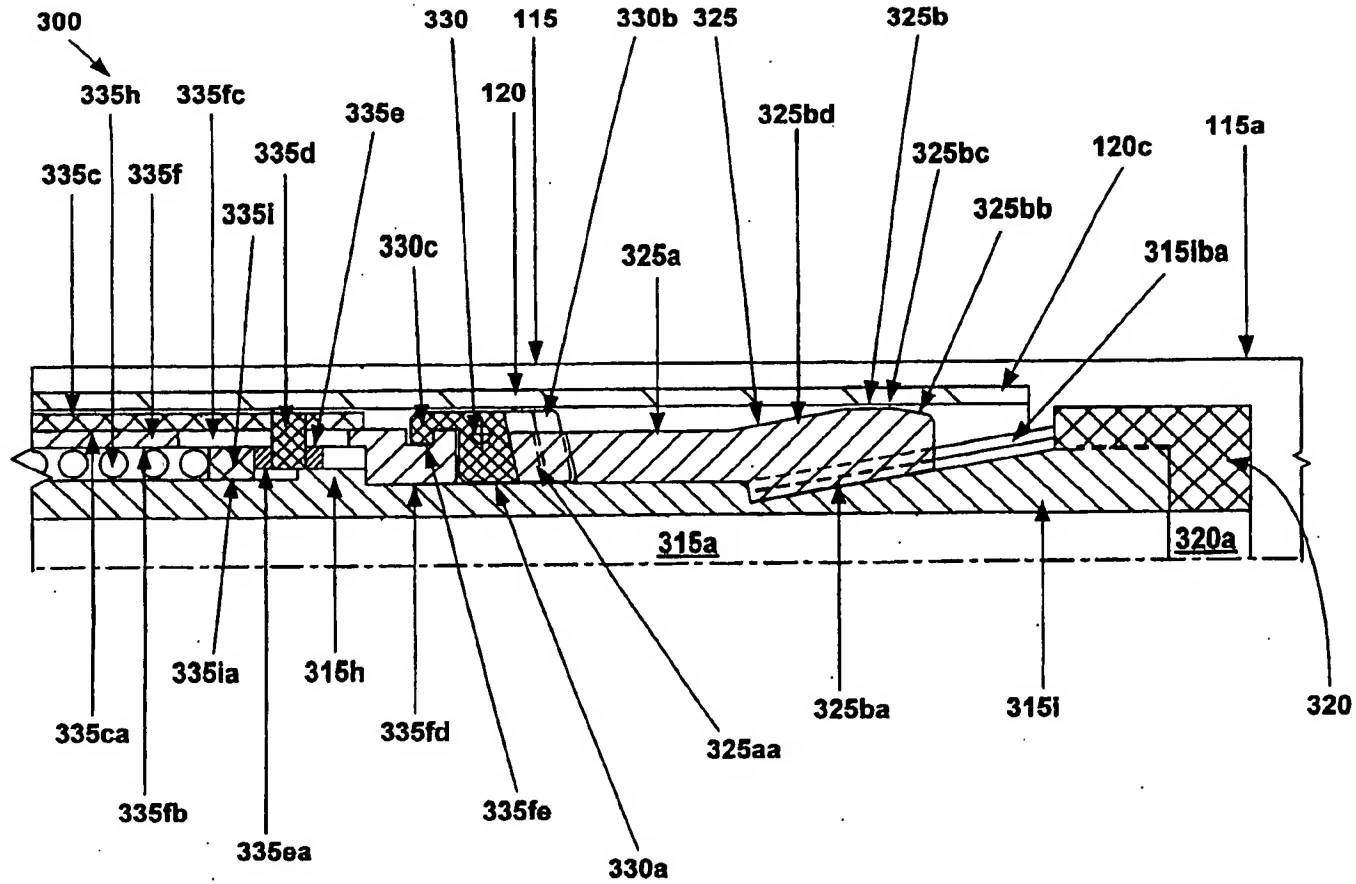
315
335aa

Fig. 4c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330c
325a
315iba
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335fb
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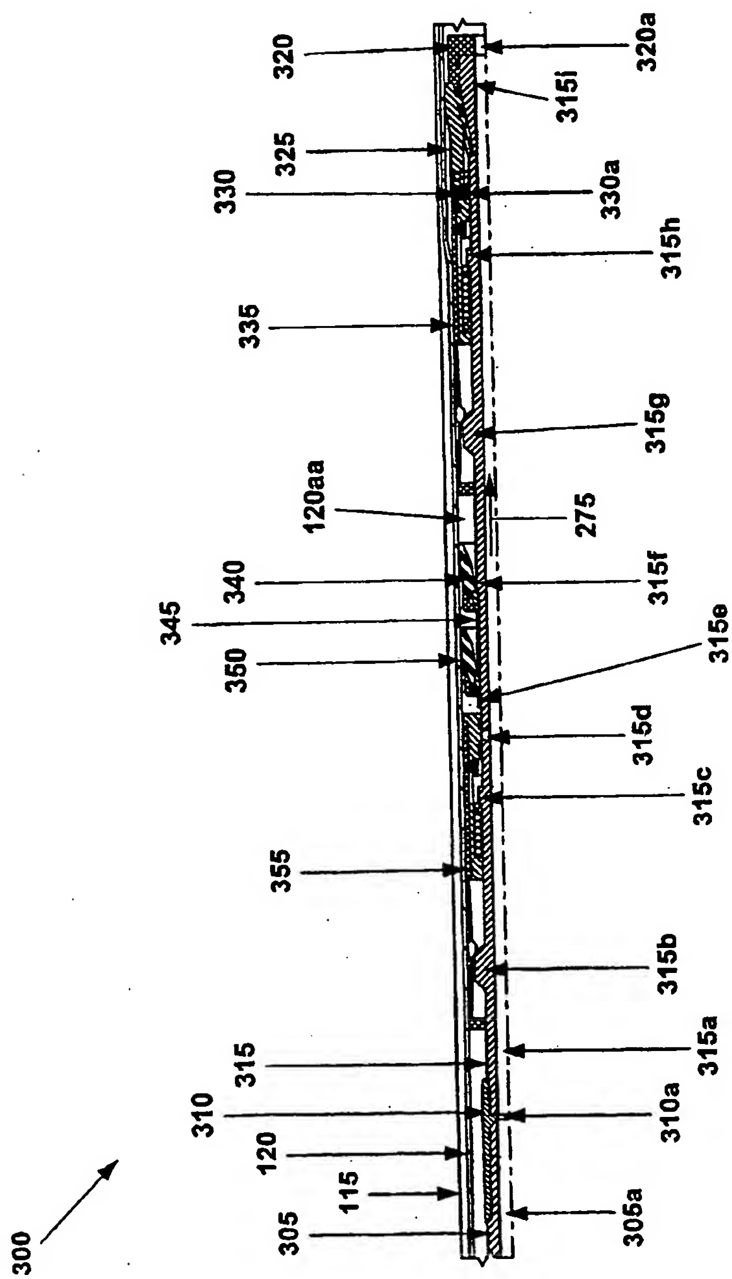
335ea
330a

Fig. 4d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315d
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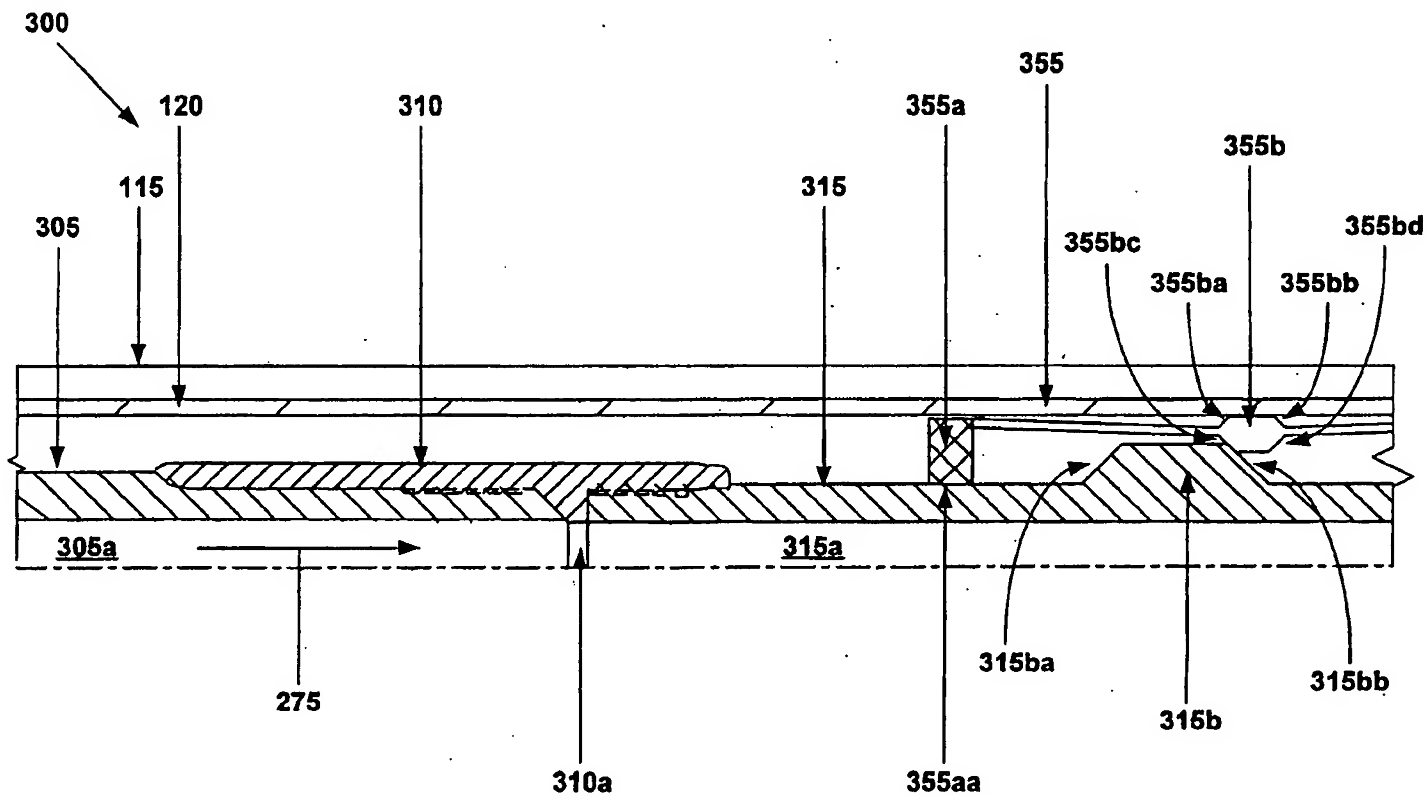
315a
310a
305a

Fig. 5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355b
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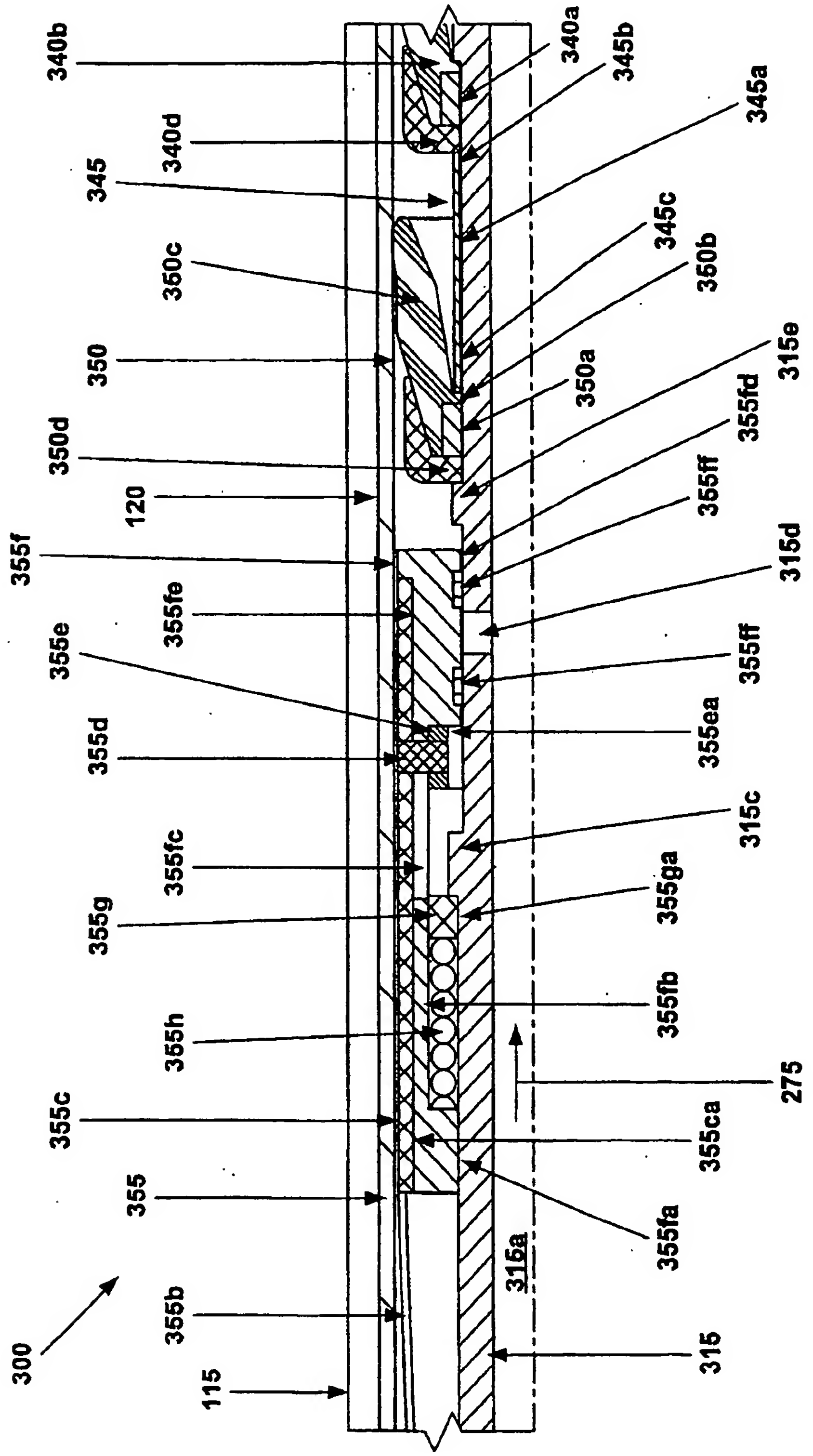
315b
315bb

Fig. 5a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340b
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345a
345c
350b
350a
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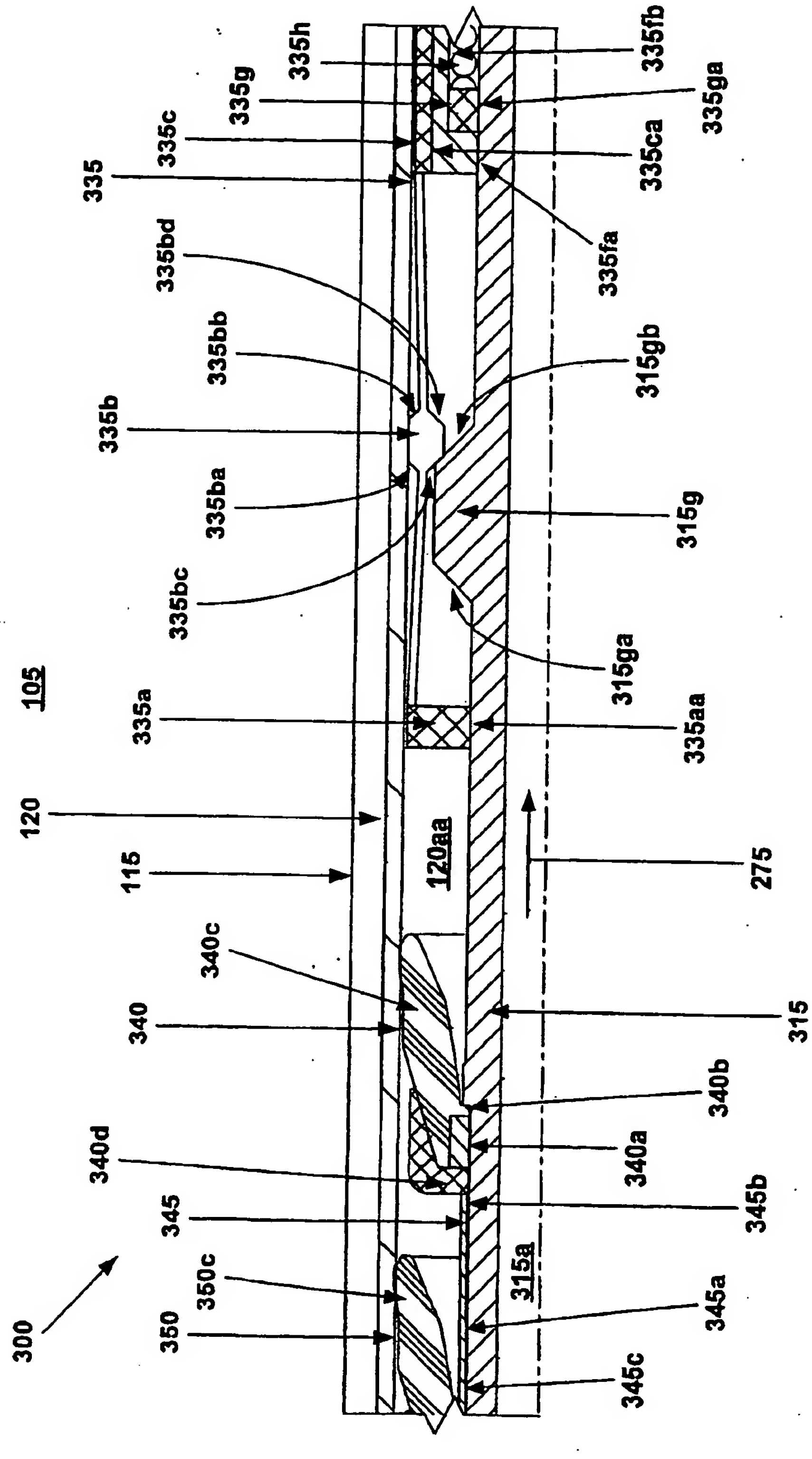
355fa
315a
315

Fig. 5b



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335b
335ba
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335c
335ca
335fa
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345c
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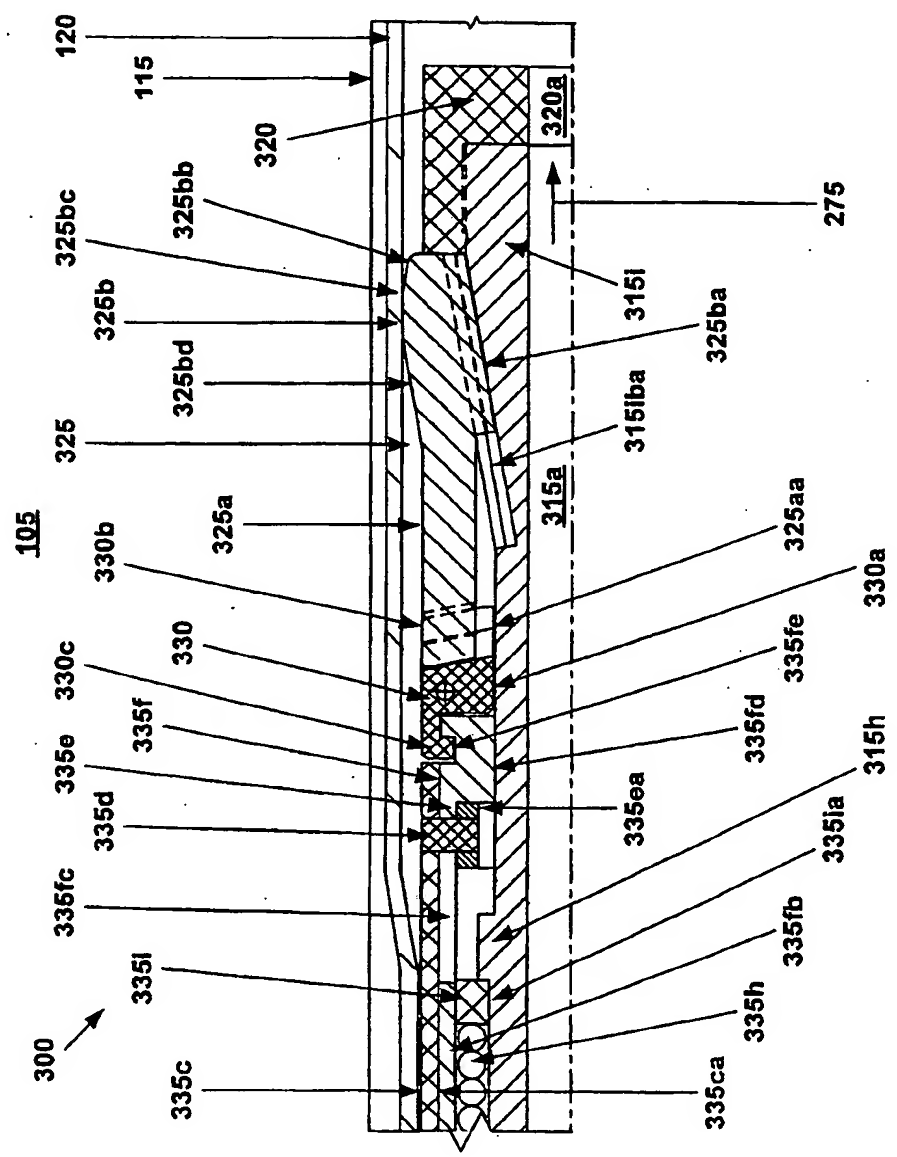
350c

Fig. 5c



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325bc
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315l
325b
325ba
325bd
315lba
325
315a
105
325a
330b
325aa
330a
330
335fe
330c
335f
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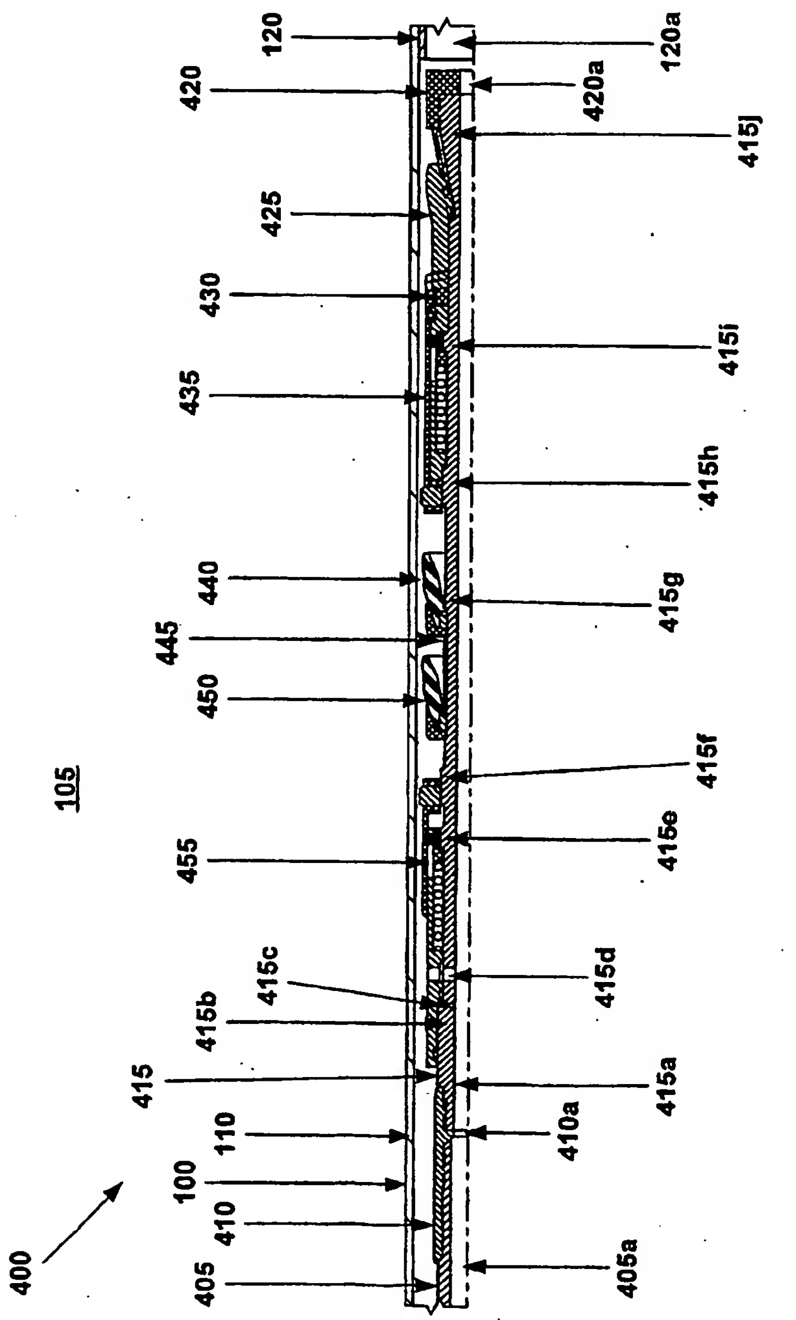
335fb
335l
335h
300
335c
335ca

Fig. 5d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440
435
430
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415f
415e
415d
415a
410a
405a

Fig. 6

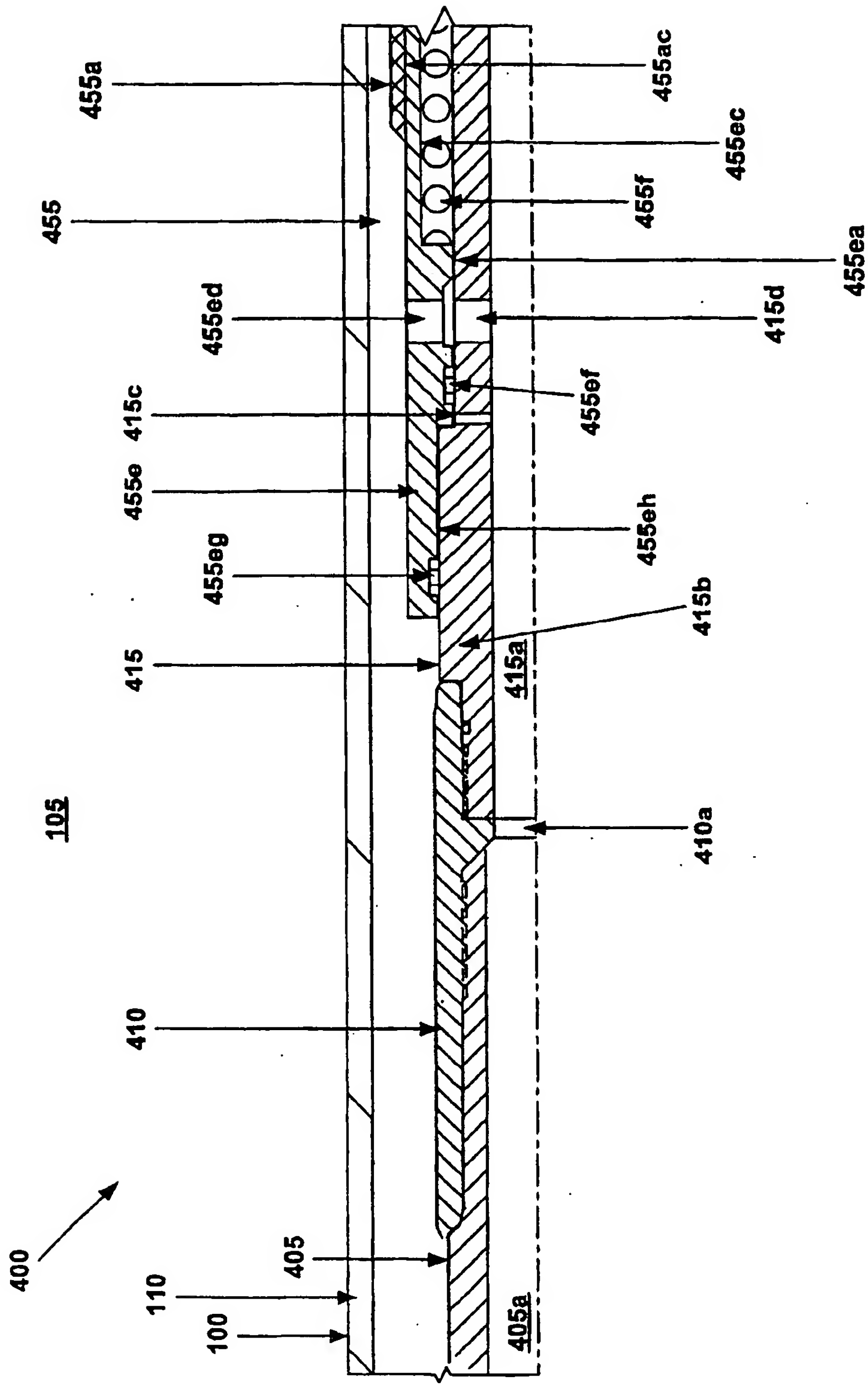
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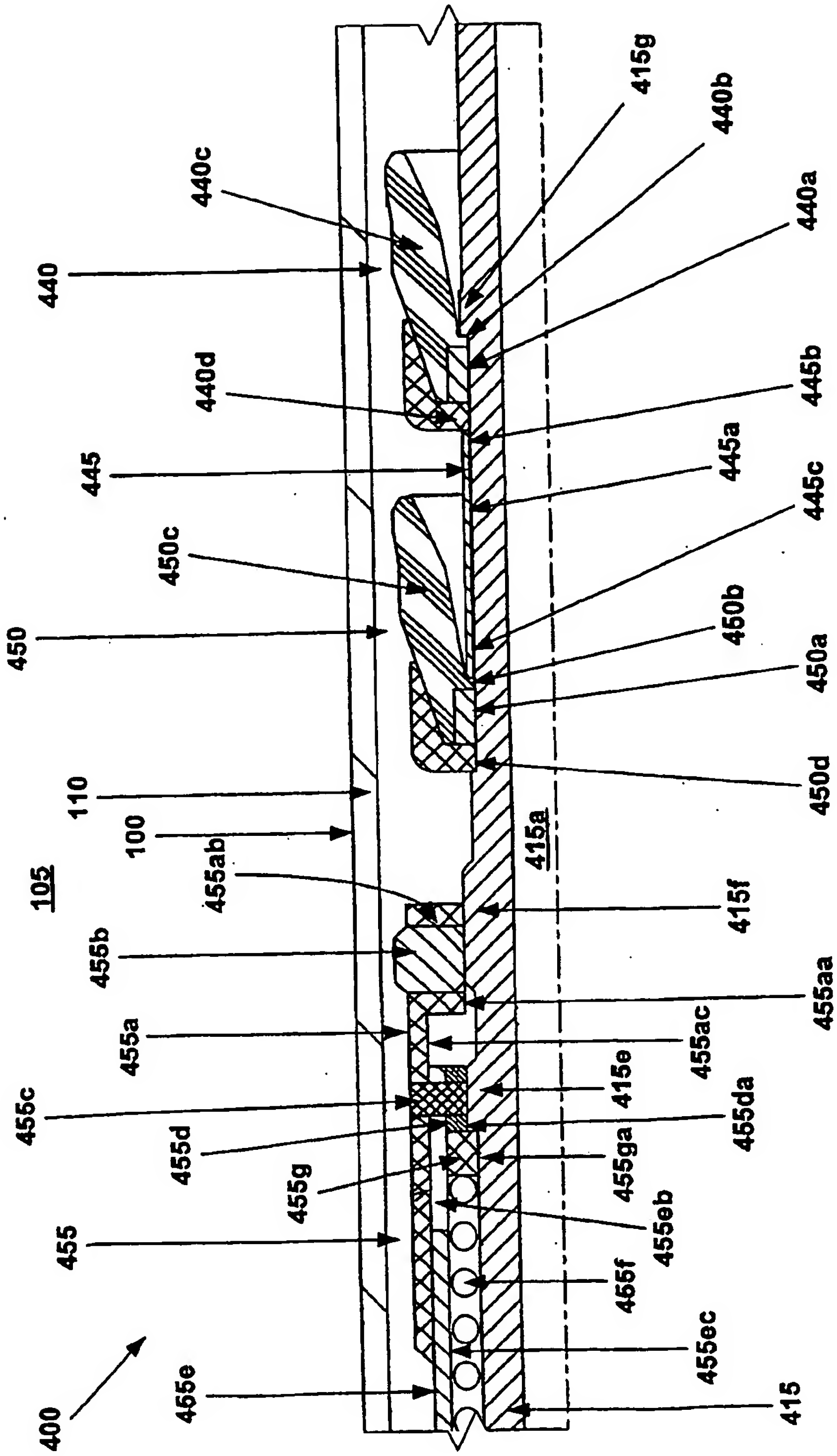
Fig. 6a



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445a
445c
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450b
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450d
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415a
415f
455b
455aa
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455eb
455
455f
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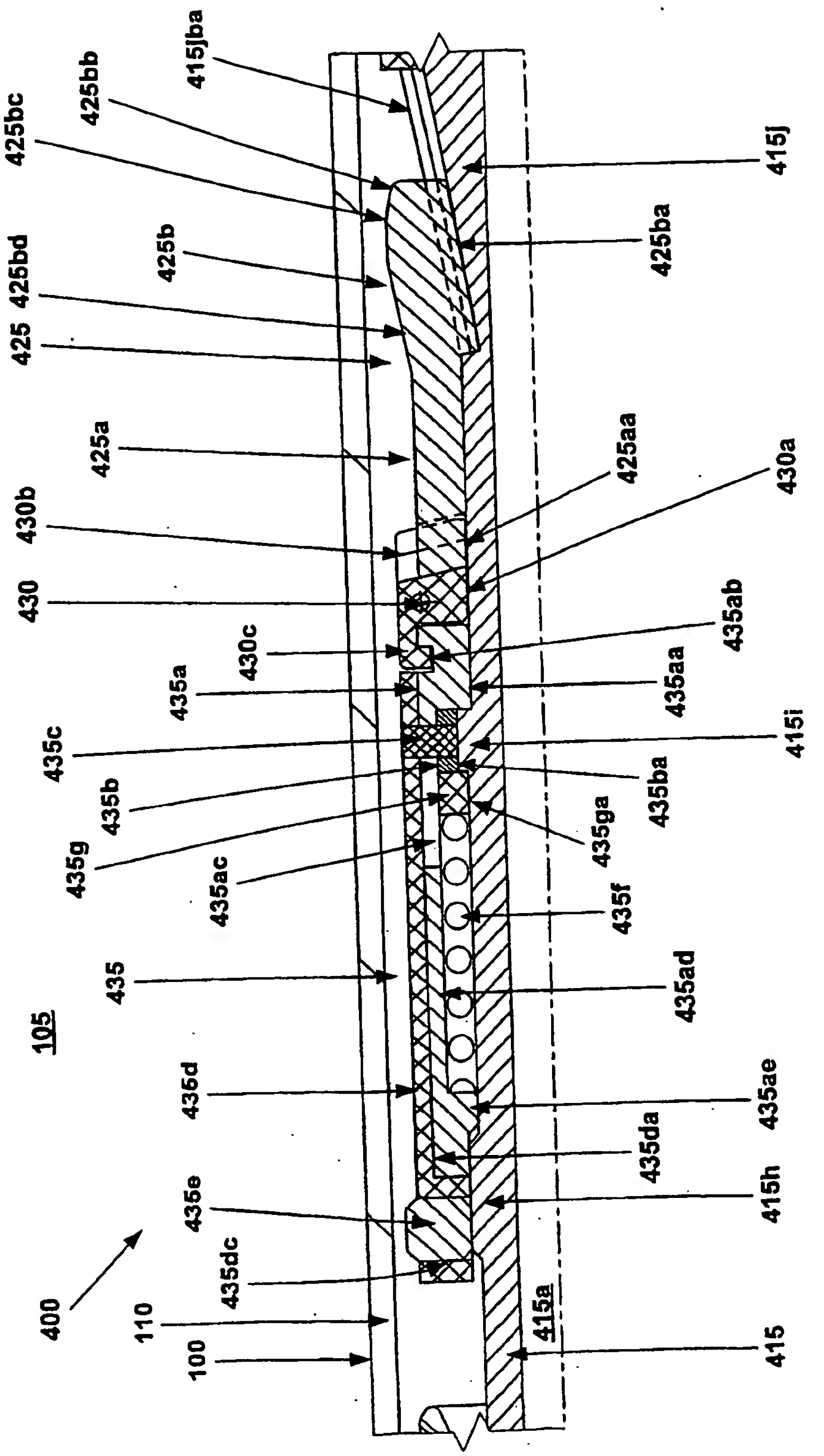
400
455e
415

Fig. 6b



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415a
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415j
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425b
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430b
430c
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435a
435aa
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Fig. 6c

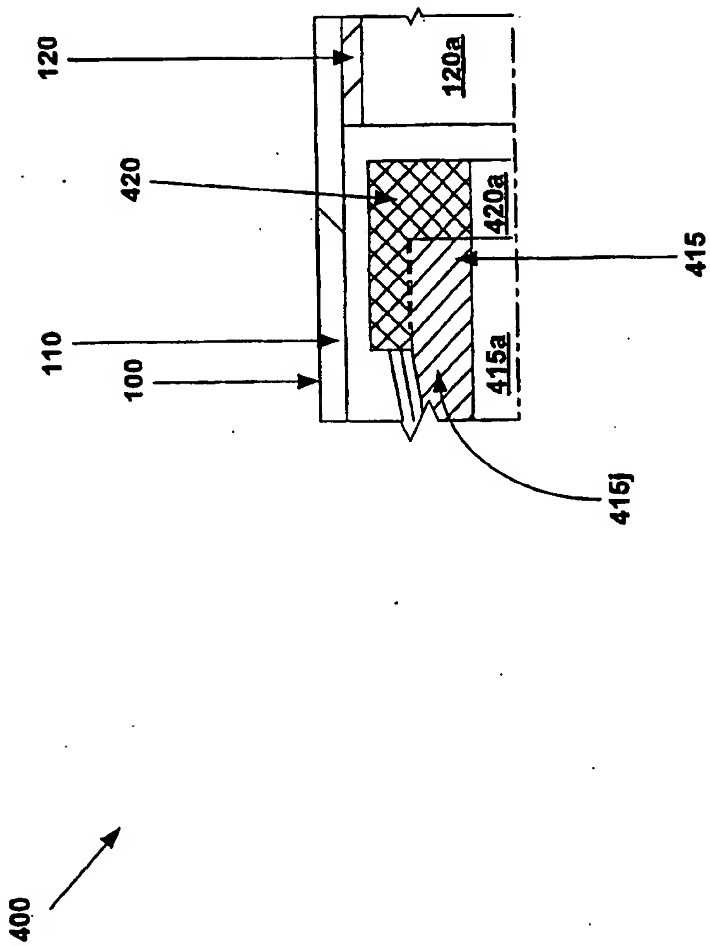

Fig. 6d

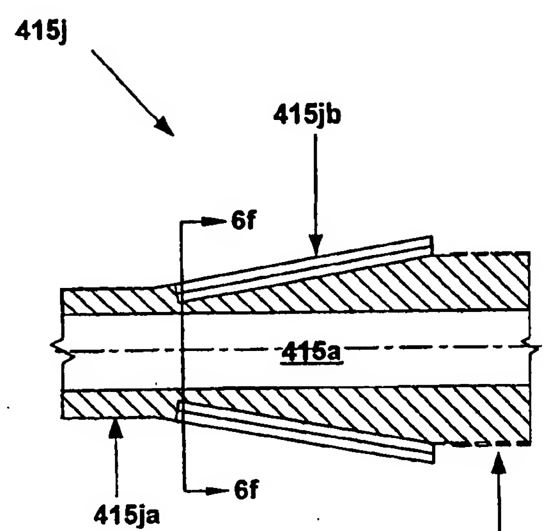
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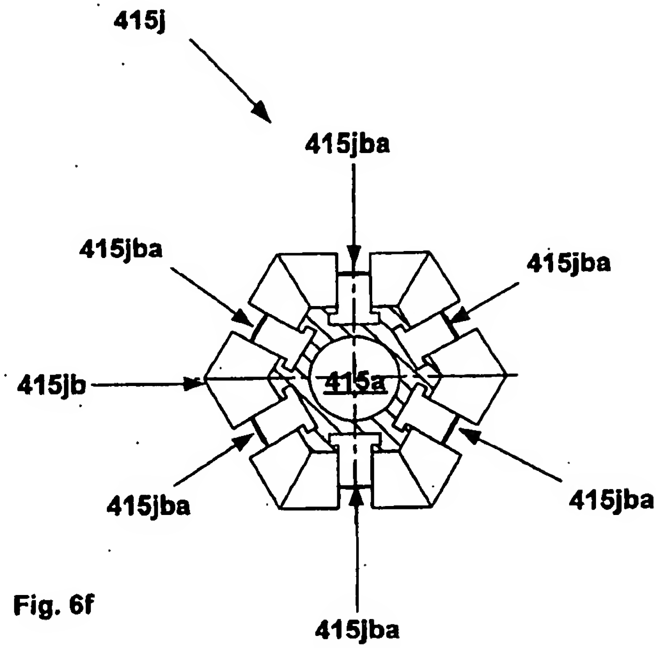
Fig. 6e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415jba

Fig. 6f

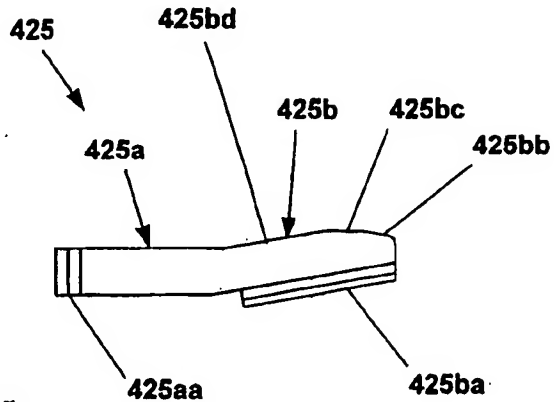


Fig. 6g

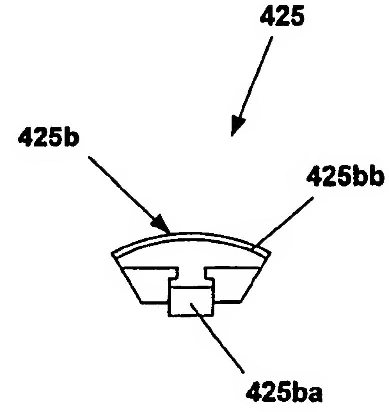


Fig. 6h

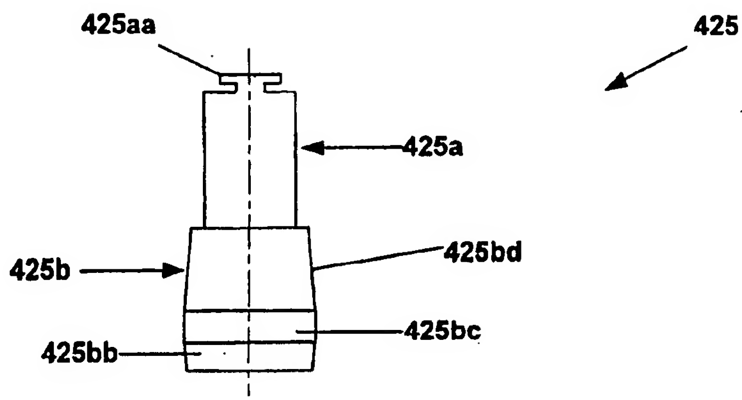
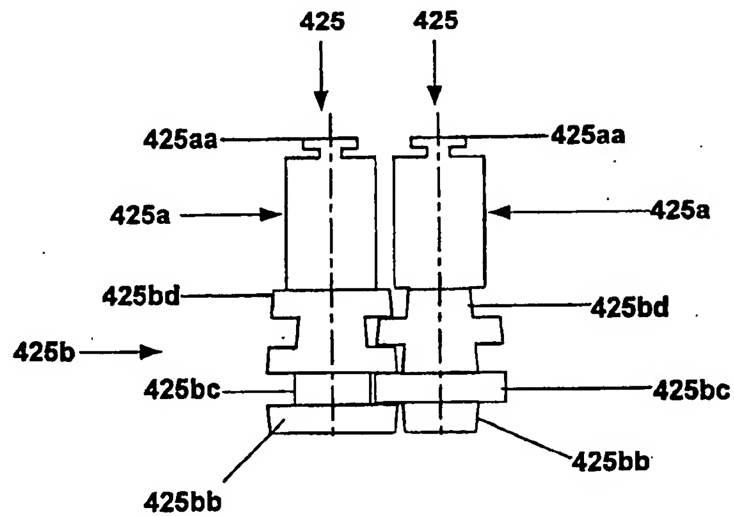


Fig. 6i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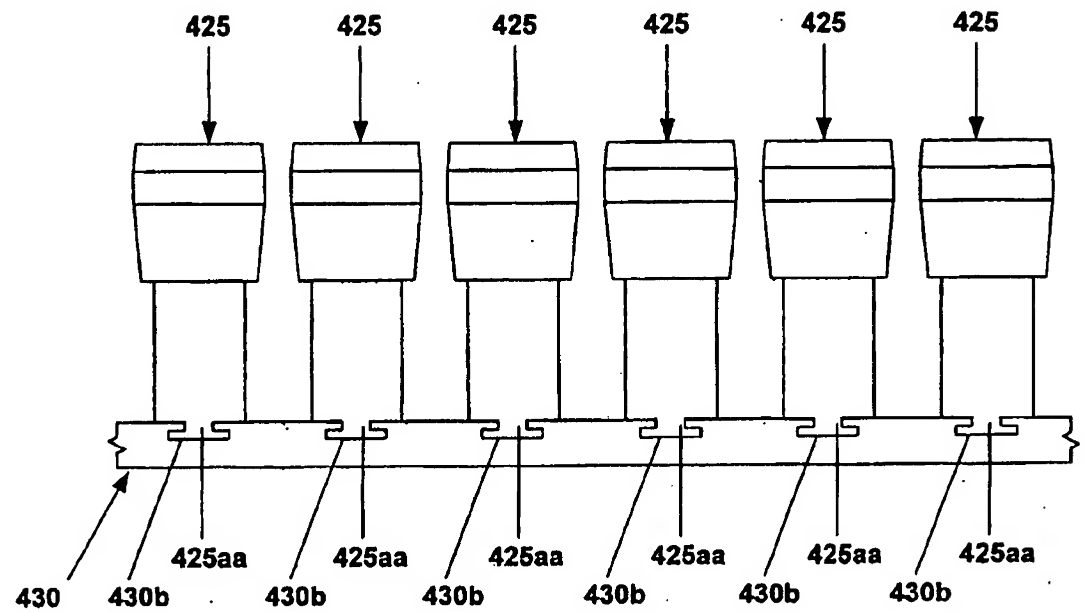
425bb

Fig. 6j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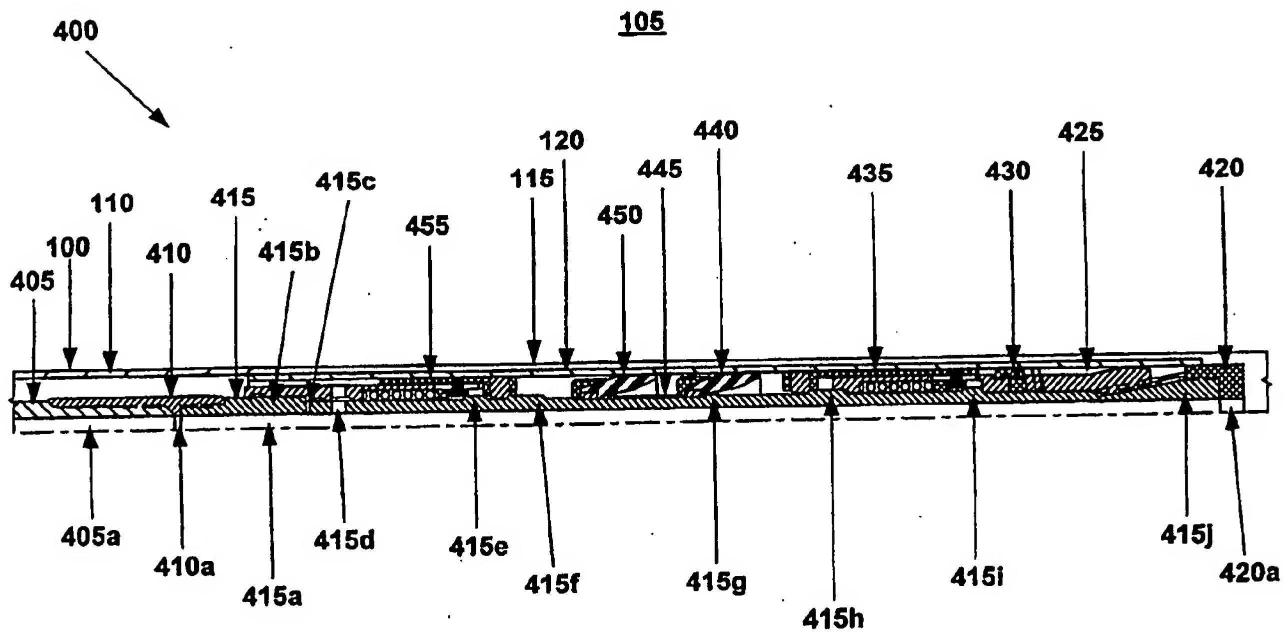
430b
425aa

Fig. 6k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415g
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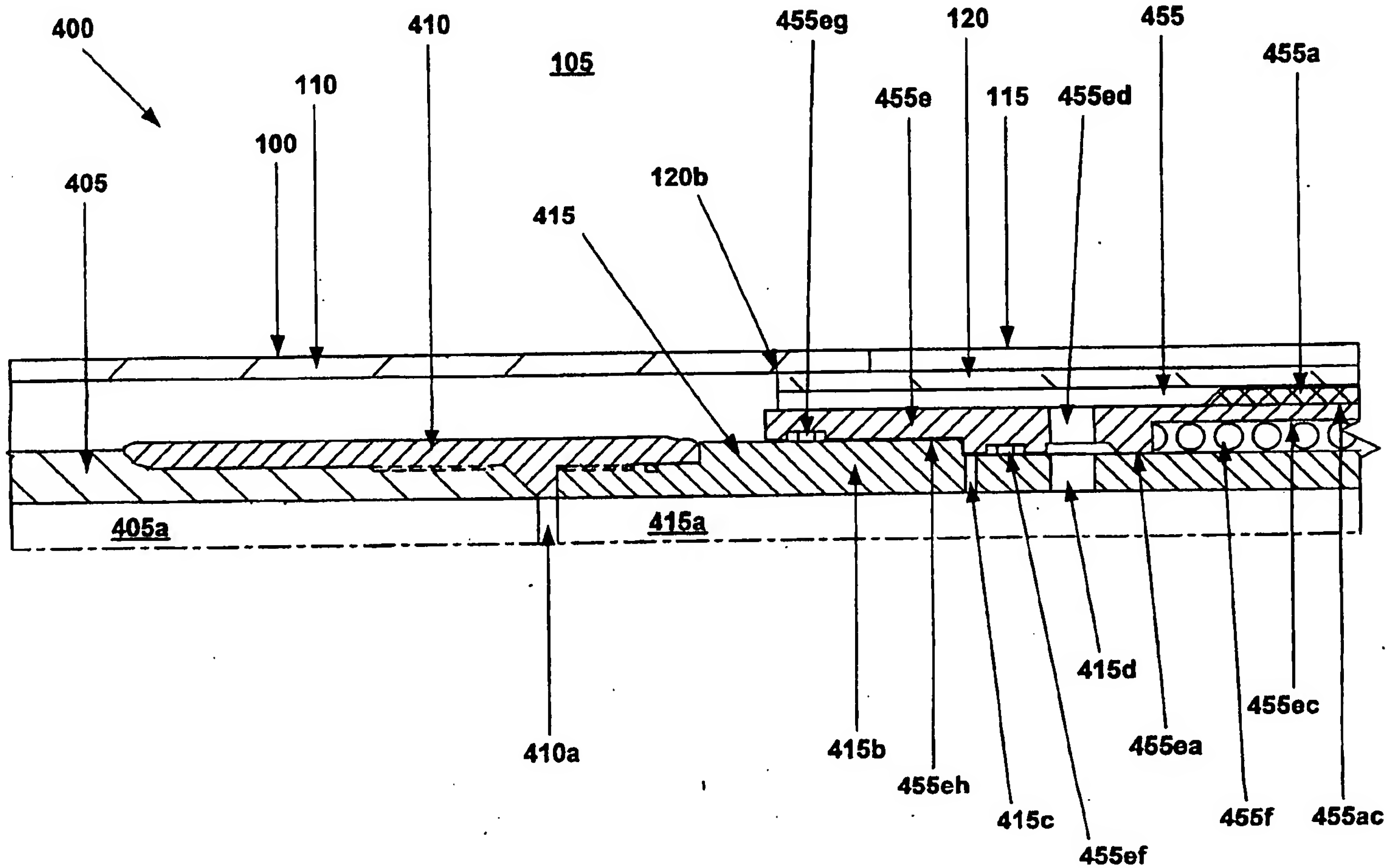
415j
420a

Fig. 7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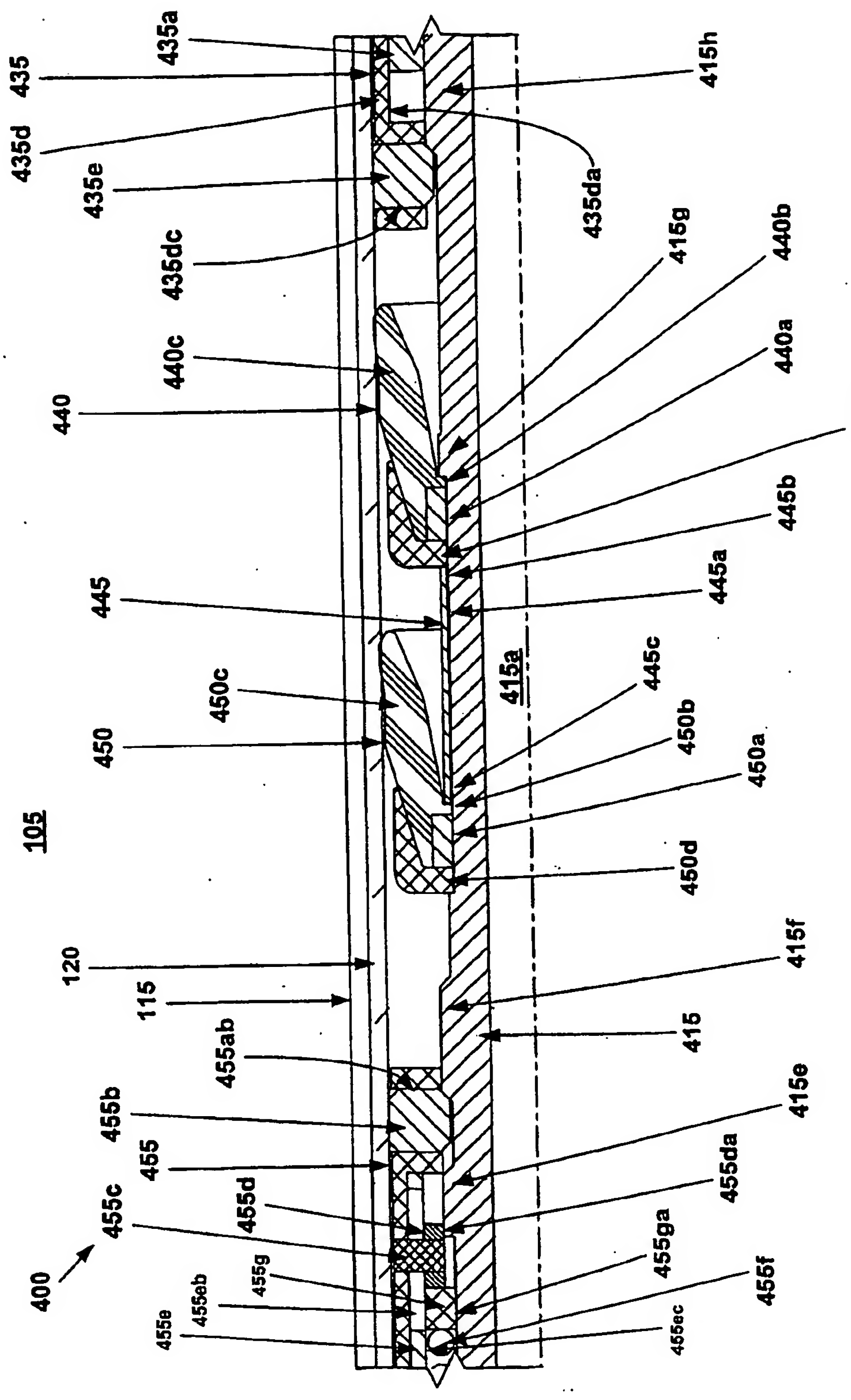
405
120b
415
405a
415a
410a
415b
455eh
415c
455ef
415d
455ea
455ec
455f
455ac

Fig. 7a



435a
435
435d
415h
435e
435da
435dc
415g
440b
440c
440a
440
440d
445b
445
445a
105
415a
445c
450c
450b
450
450a
450d
120
415f
115
415
455ab
415e
455b
455
455da
455c
455d
455ga
400
455g
455f
455eb
455e
455ec

Fig. 7b

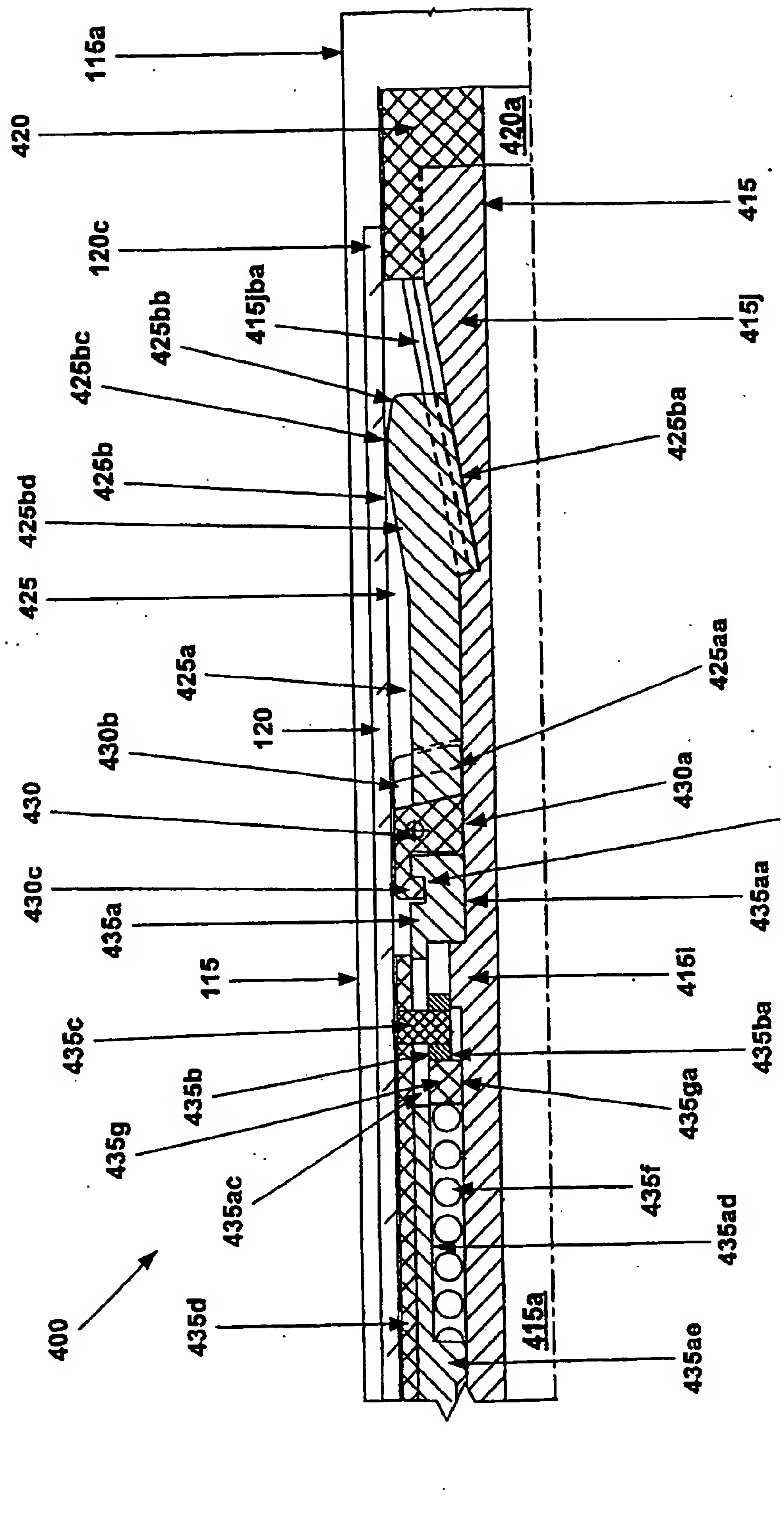
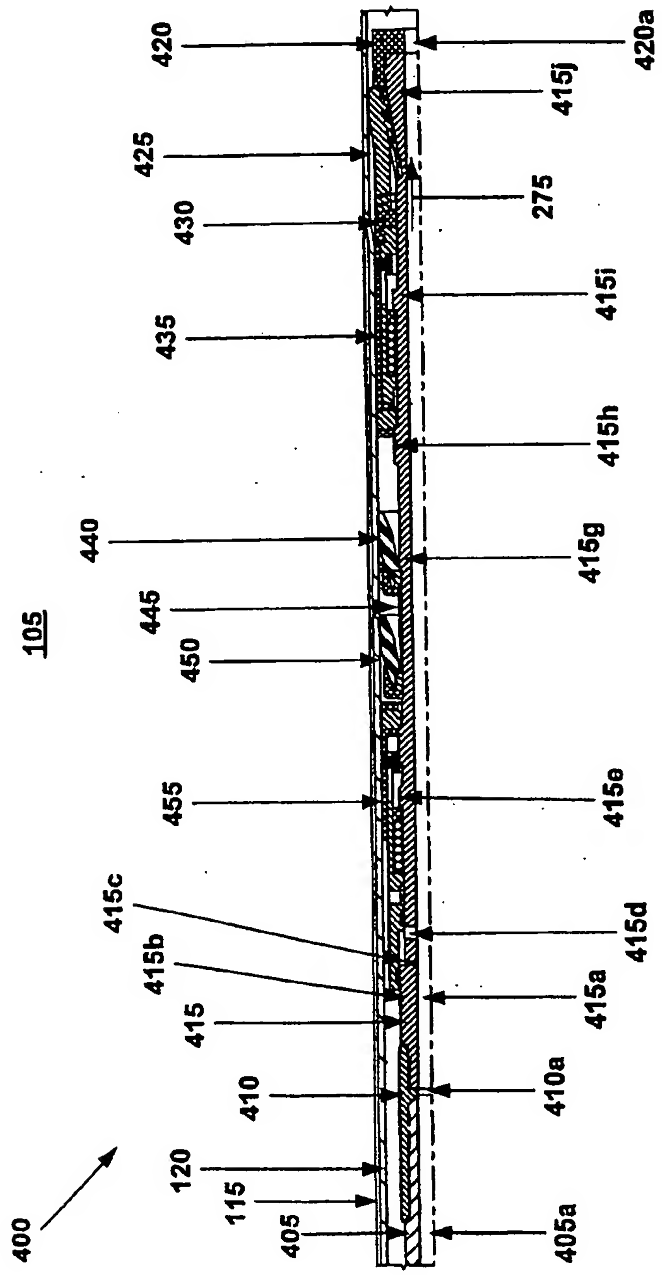
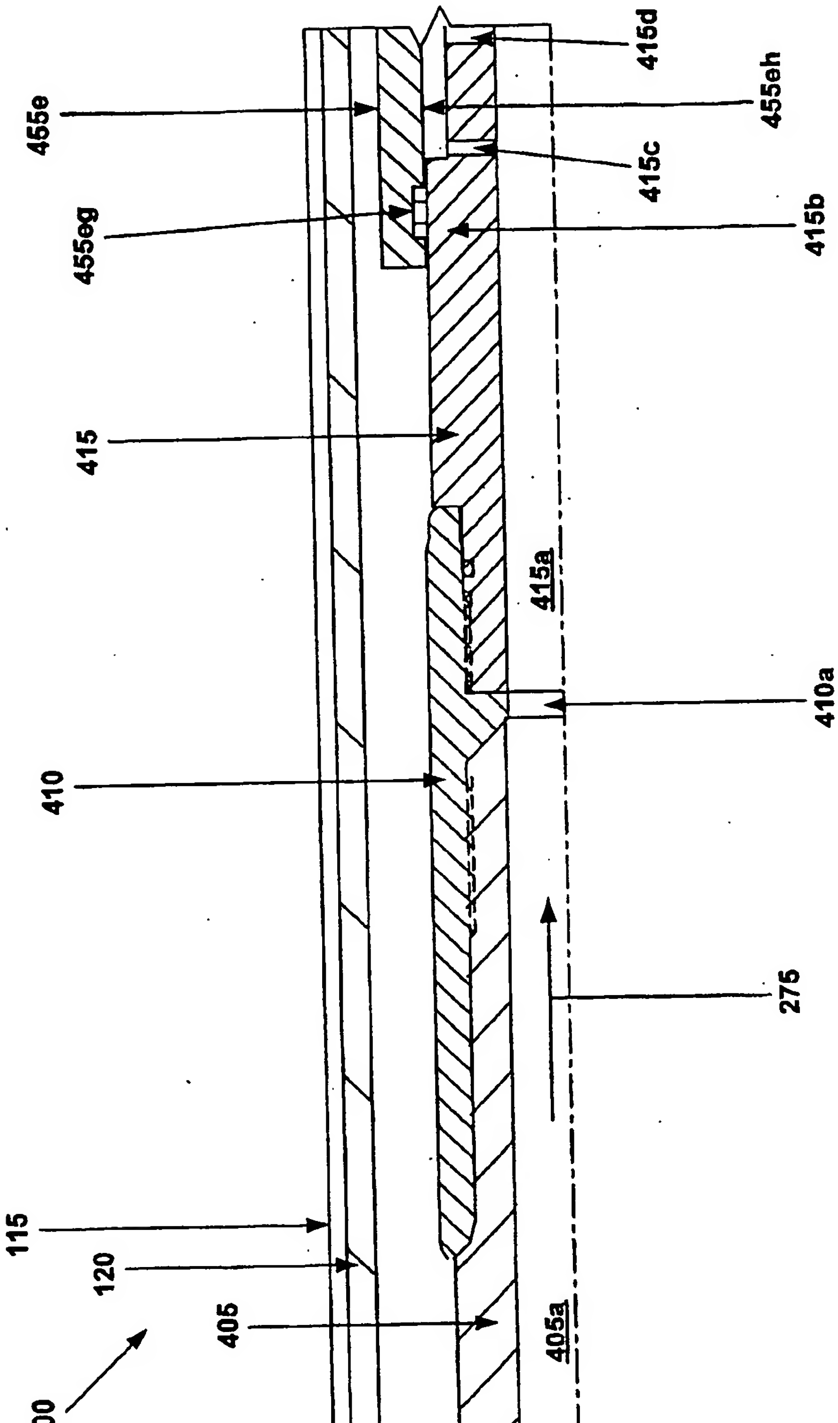

115a
420
420a
415
120c
415jba
415j
425bb
425bc
425ba
425b
425bd
425
425a
425aa
120
430b
430a
430
435ab
430c
435aa
435a
115
415l
435c
435ba
435b
435ga
435g
435ac
435f
435ad
400
435d
415a
435ae

Fig. 7c



400
105
405
115
120
410
415
415b
415c
455
450
445
440
435
430
425
420
420a
415j
275
415i
415h
415g
415e
415d
415a
410a
405a

Fig. 8



455e
455eg
415
410
115
120
400
405
415d
455eh
415c
415b
415a
410a
275
405a

Fig. 8a

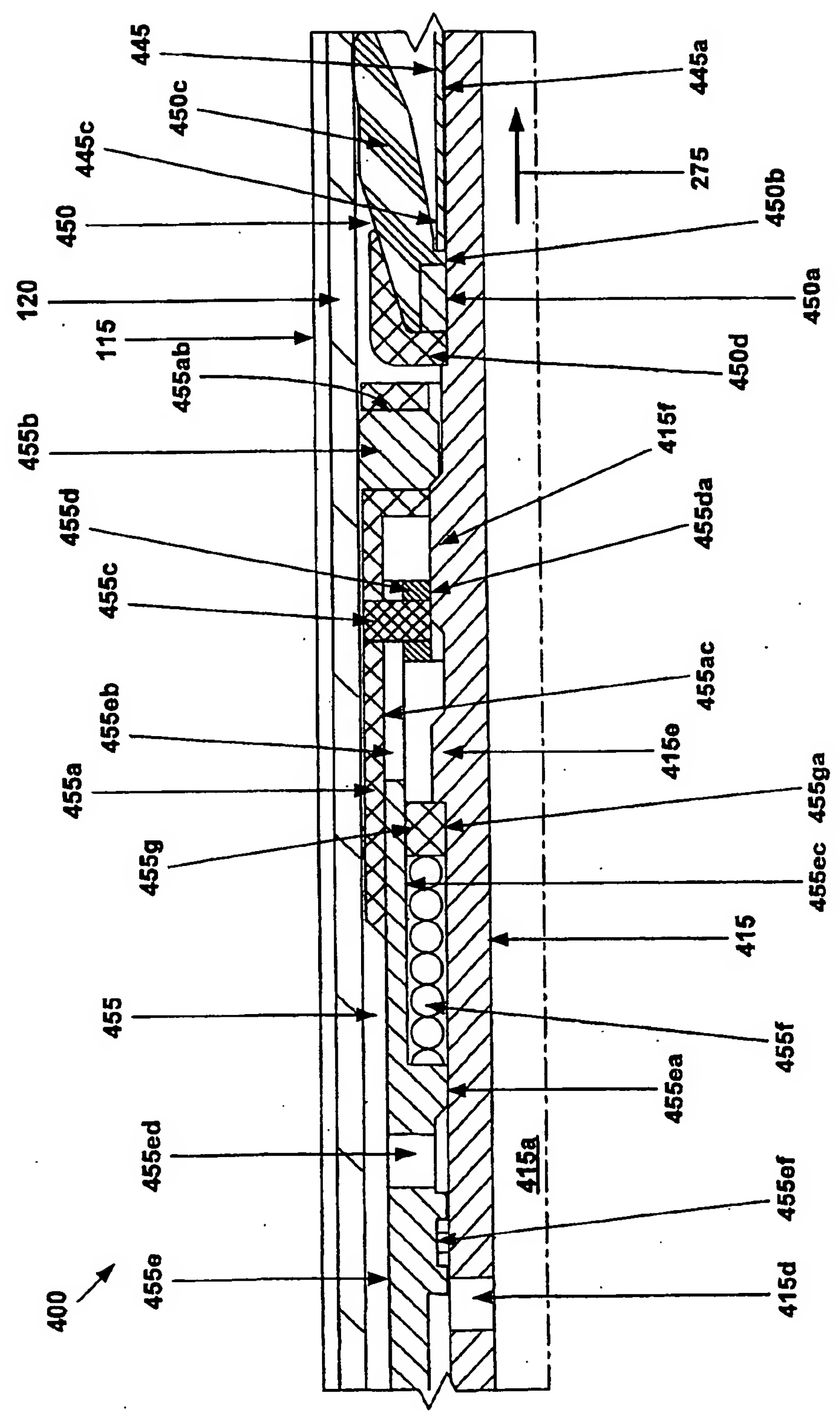

445
445a
450c
445c
275
450b
450
450a
120
115
450d
455ab
455b
415f
455d
455da
455c
455ac
455eb
415e
455a
455ga
455g
455ec
415
455
455f
455ea
455ed
415a
455ef
400
455e
415d

Fig. 8b

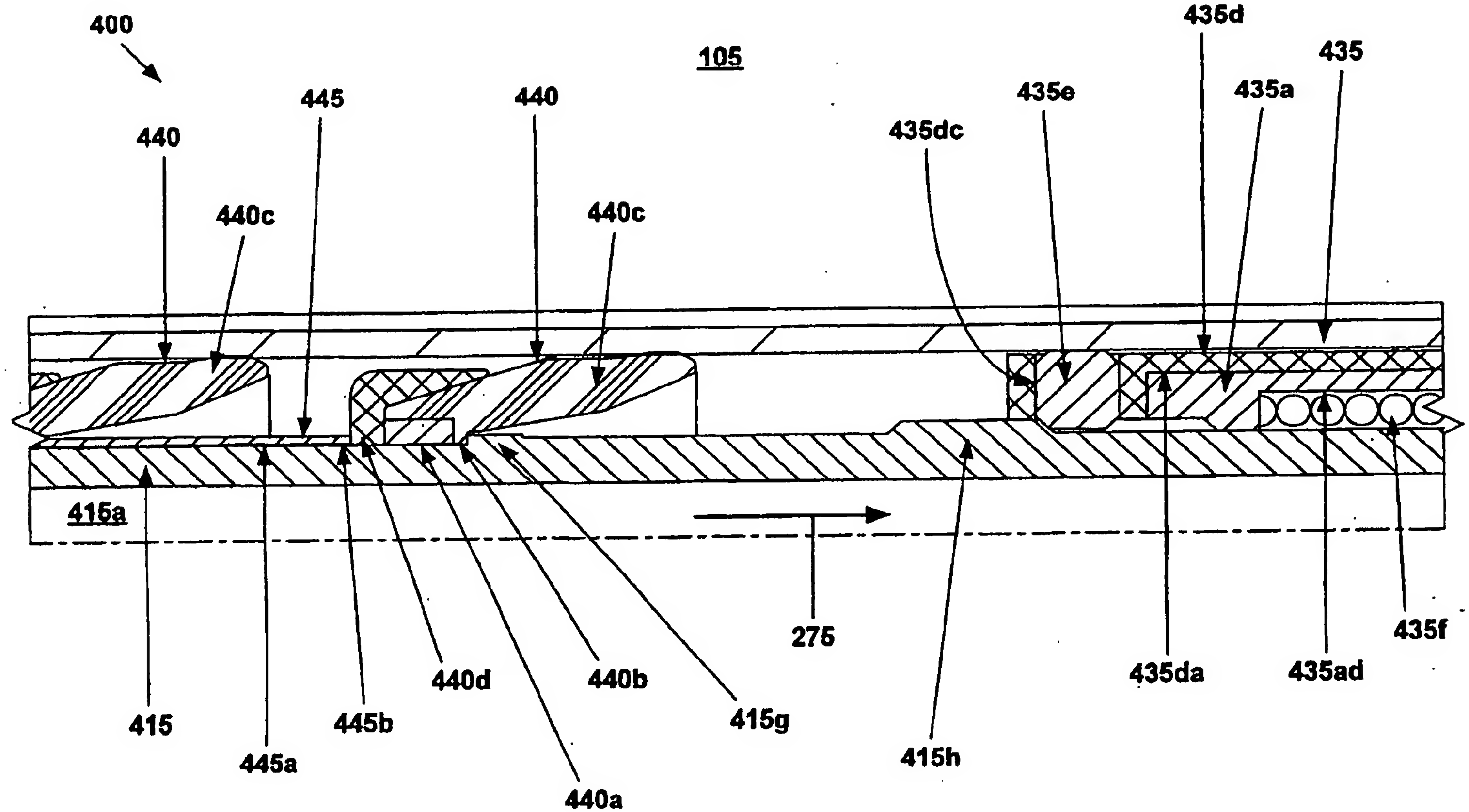
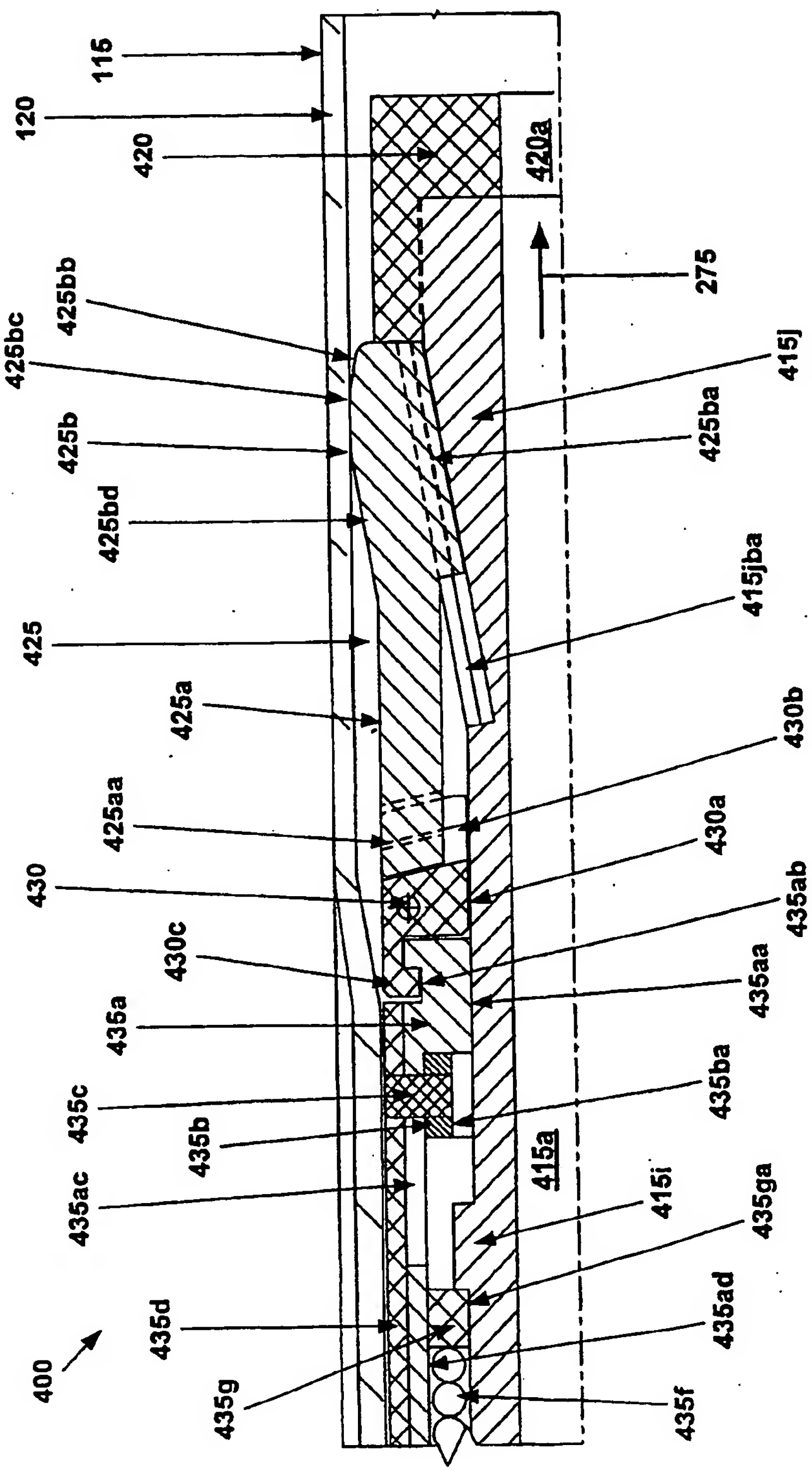

400
105
440
445
440
440c
440c
435dc
435e
435d
435a
435
415a
415
445a
445b
440d
440a
440b
415g
275
415h
435da
435ad
435f

Fig. 8c



115
120
420
420a
275
425bb
425bc
415j
425b
425ba
425bd
415jba
425
425a
430b
425aa
430a
430
435ab
430c
435aa
435a
435ba
435c
415a
435b
415i
435ac
435ga
435d
435ad
400
435g
435f

Fig. 8d

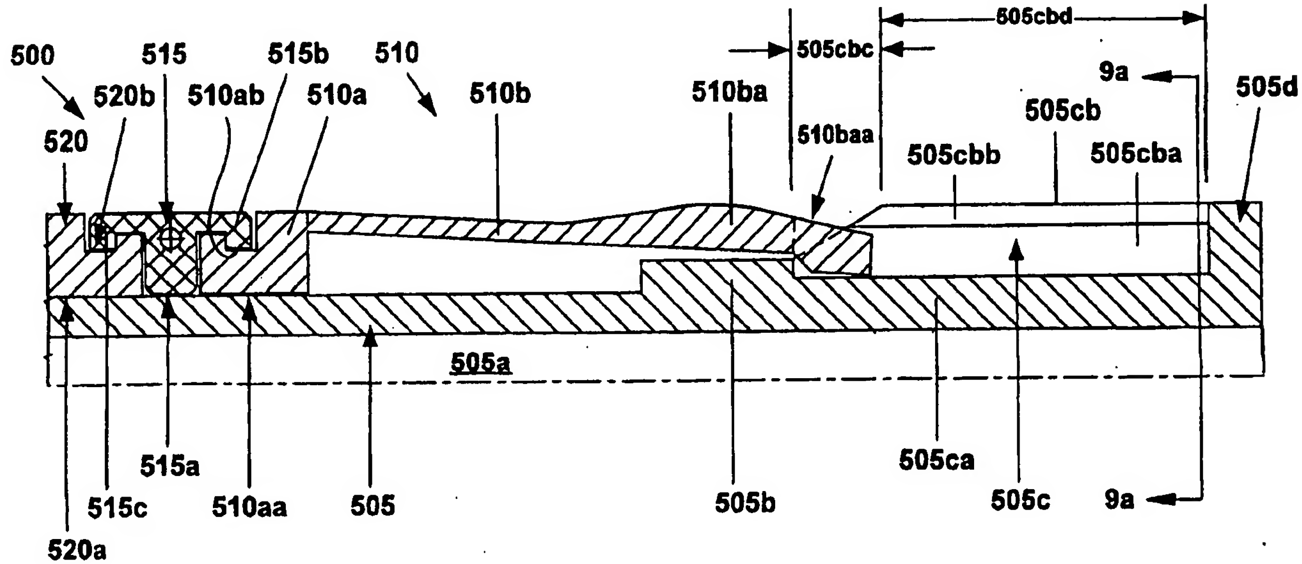

500
520
520b
515
510ab
515b
510a
510
510b
510ba
505cbc
505cbd
510baa
505cbb
505cb
505cba
9a
505d
505a
520a
515c
515a
510aa
505
505b
505ca
505c
9a

Fig. 9

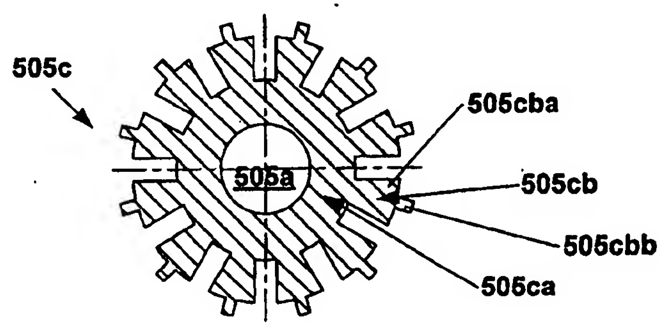

505c
505a
505cba
505cb
505cbb
505ca

Fig. 9a

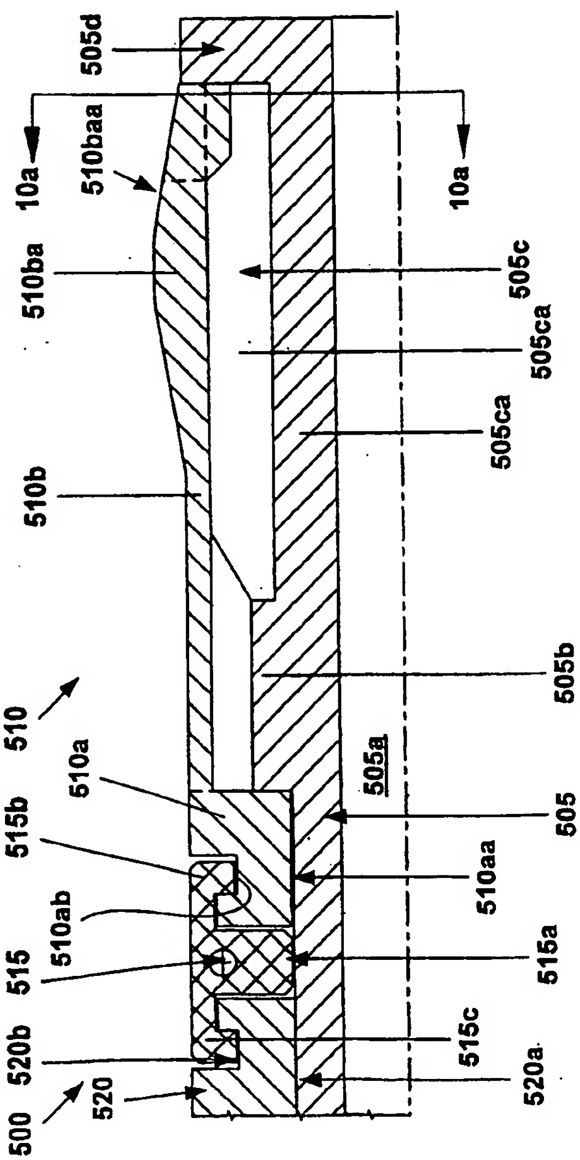


Fig. 10

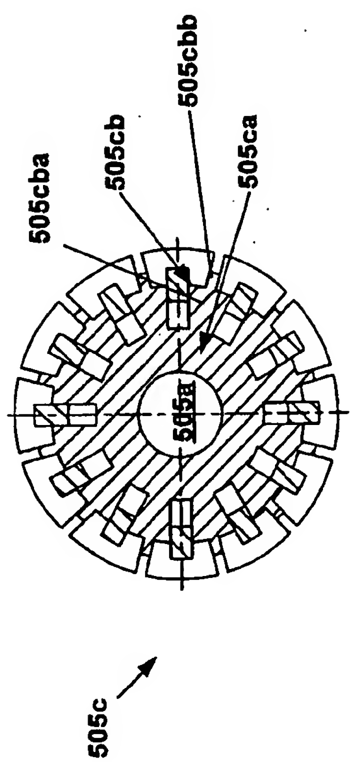


Fig. 10a

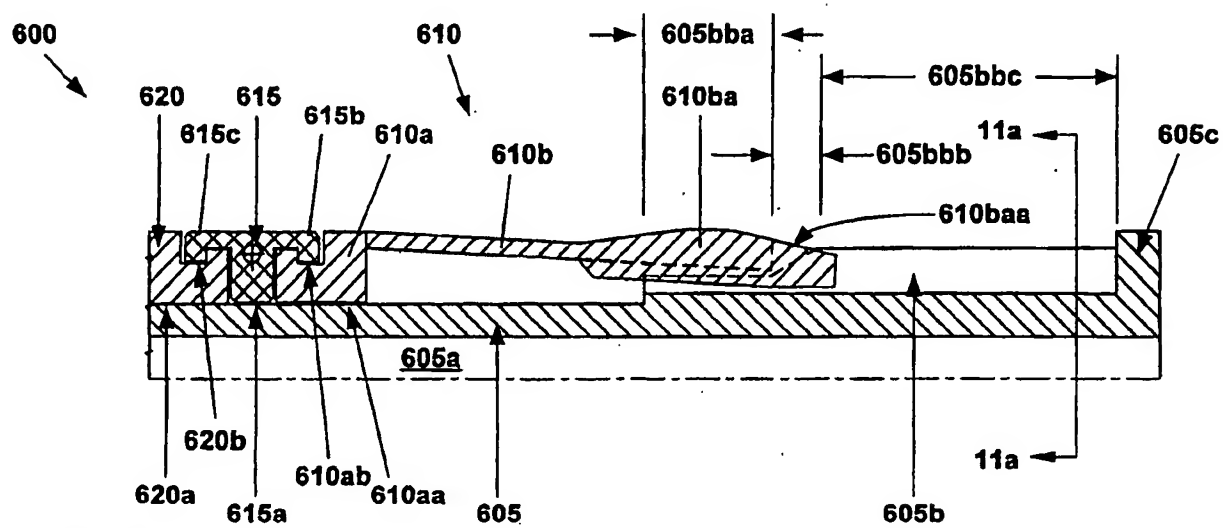


Fig. 11

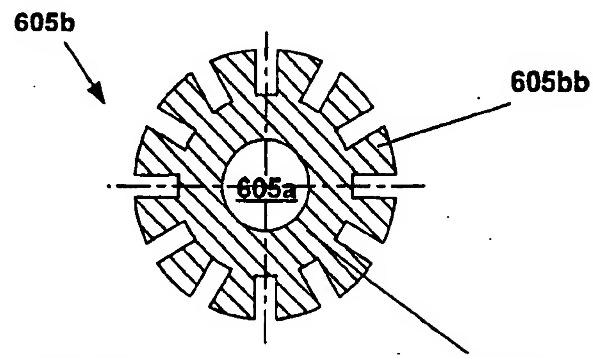


Fig. 11a

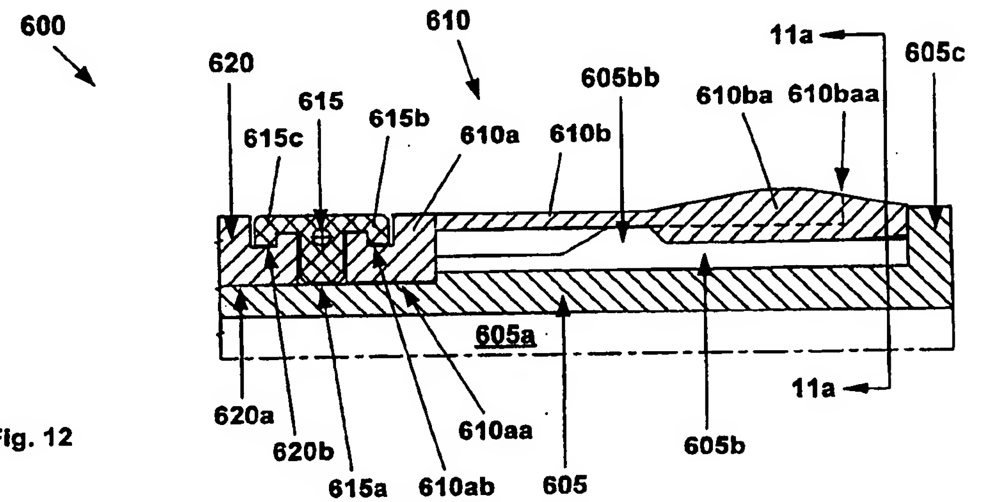


Fig. 12

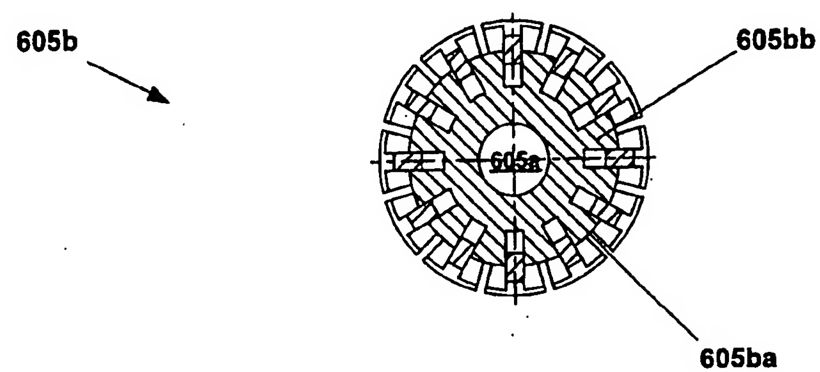


Fig. 12a

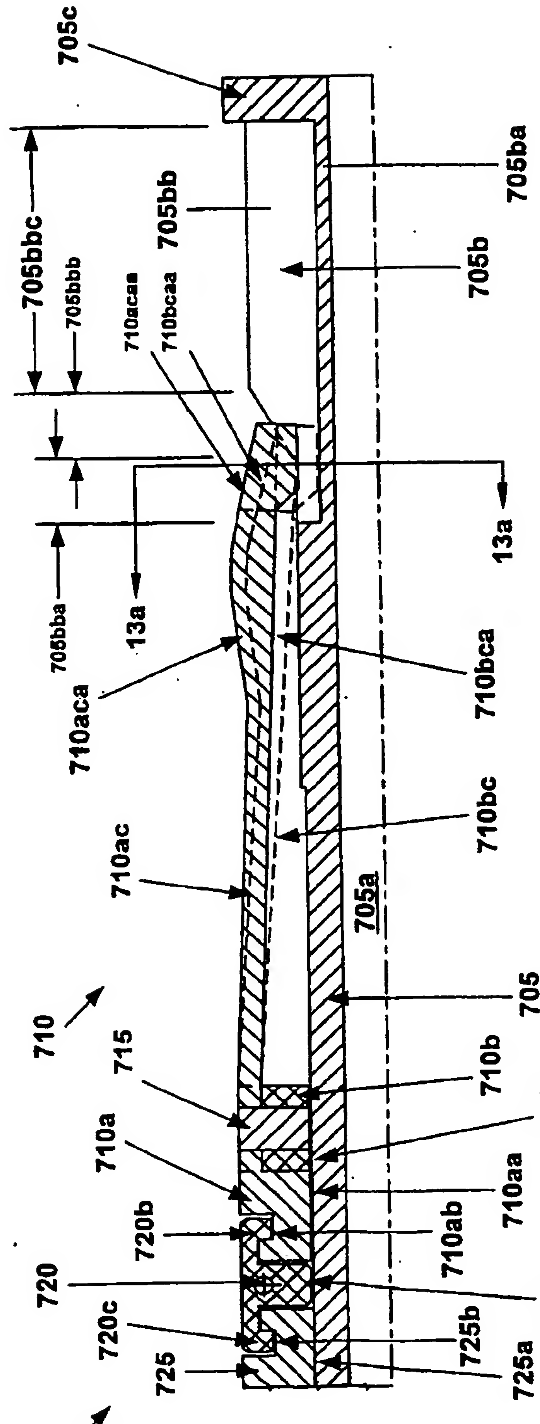


Fig . 13

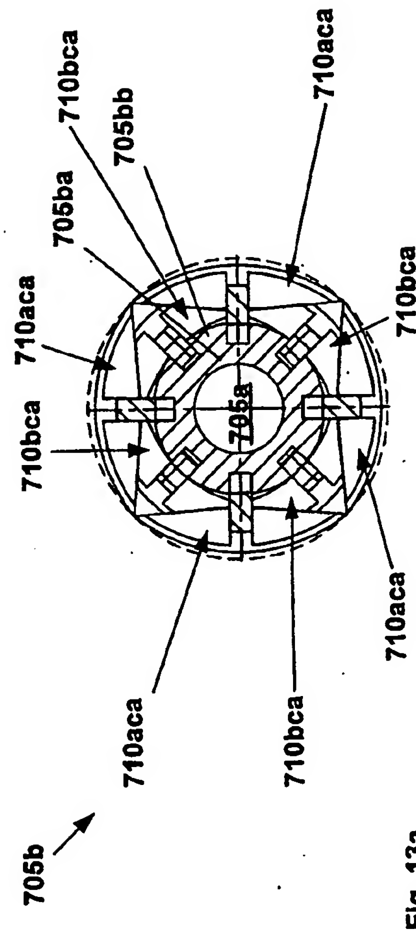


Fig. 13a

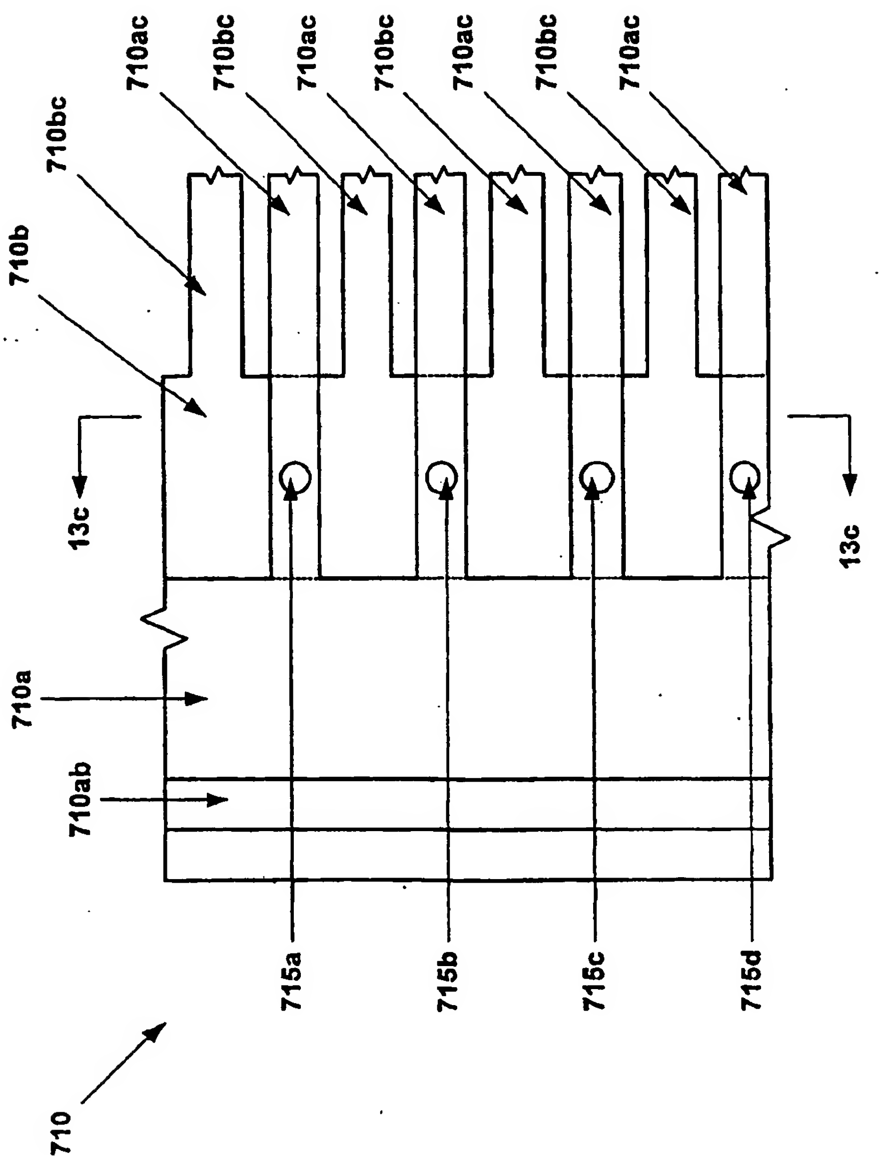

710
710ab
710a
710b
710bc
710ac
710bc
710ac
710bc
710ac
710bc
710ac
13c
13c
715a
715b
715c
715d

Fig. 13b

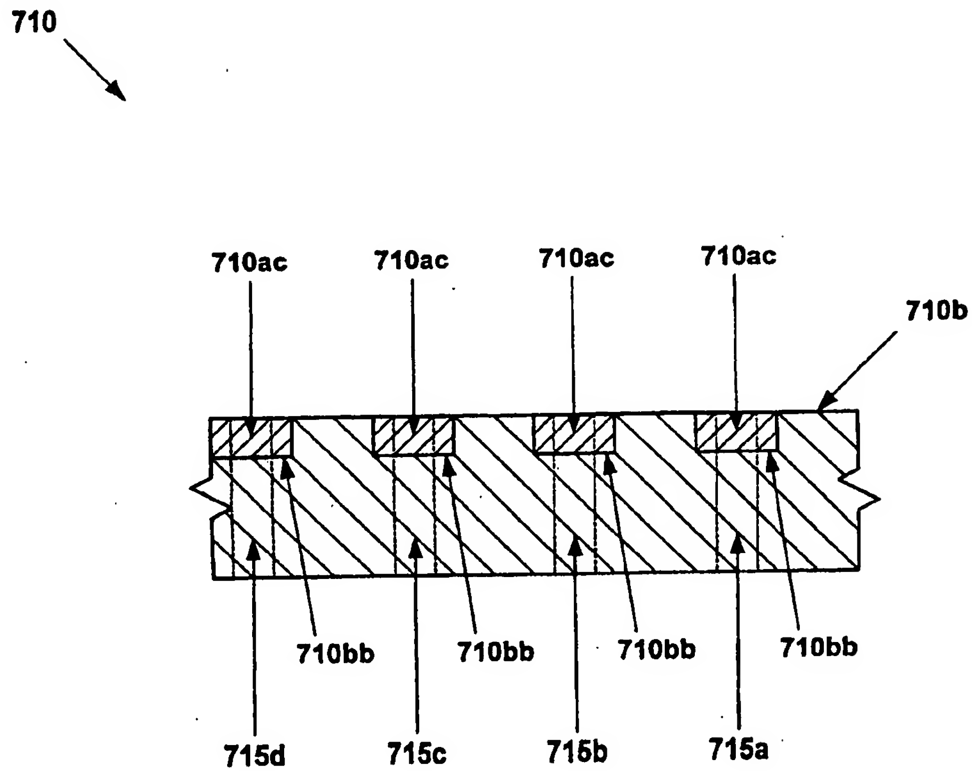

710
710ac
710ac
710ac
710ac
710b
710bb
710bb
710bb
710bb
715d
715c
715b
715a

Fig. 13c

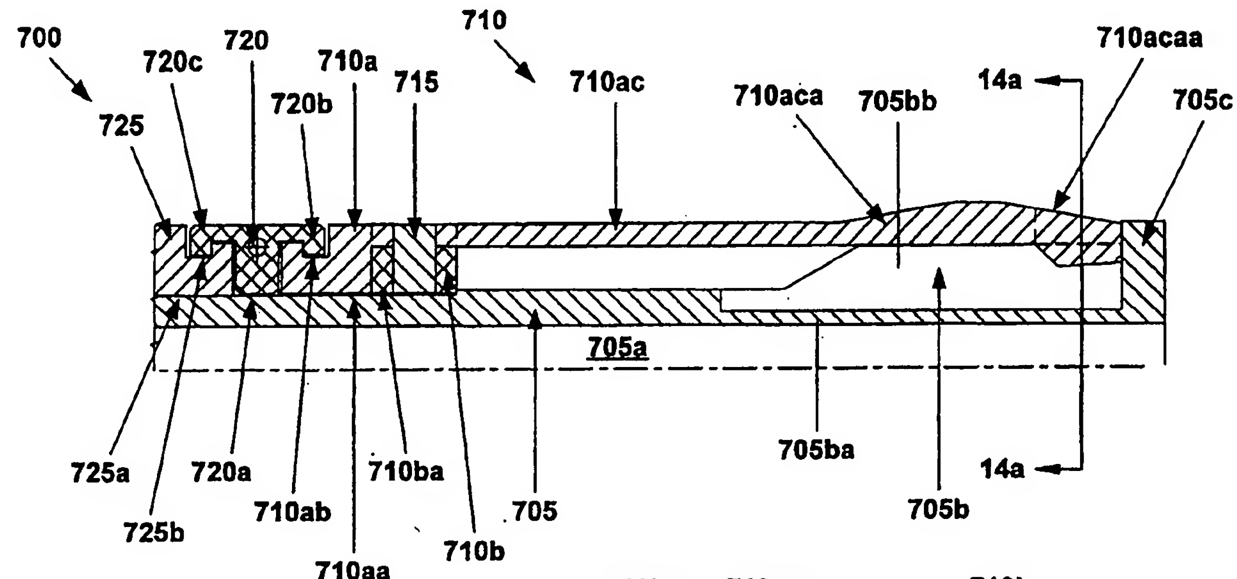


Fig. 14

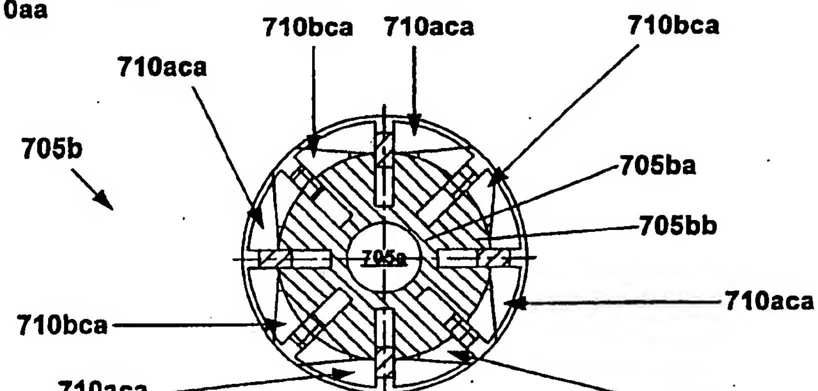
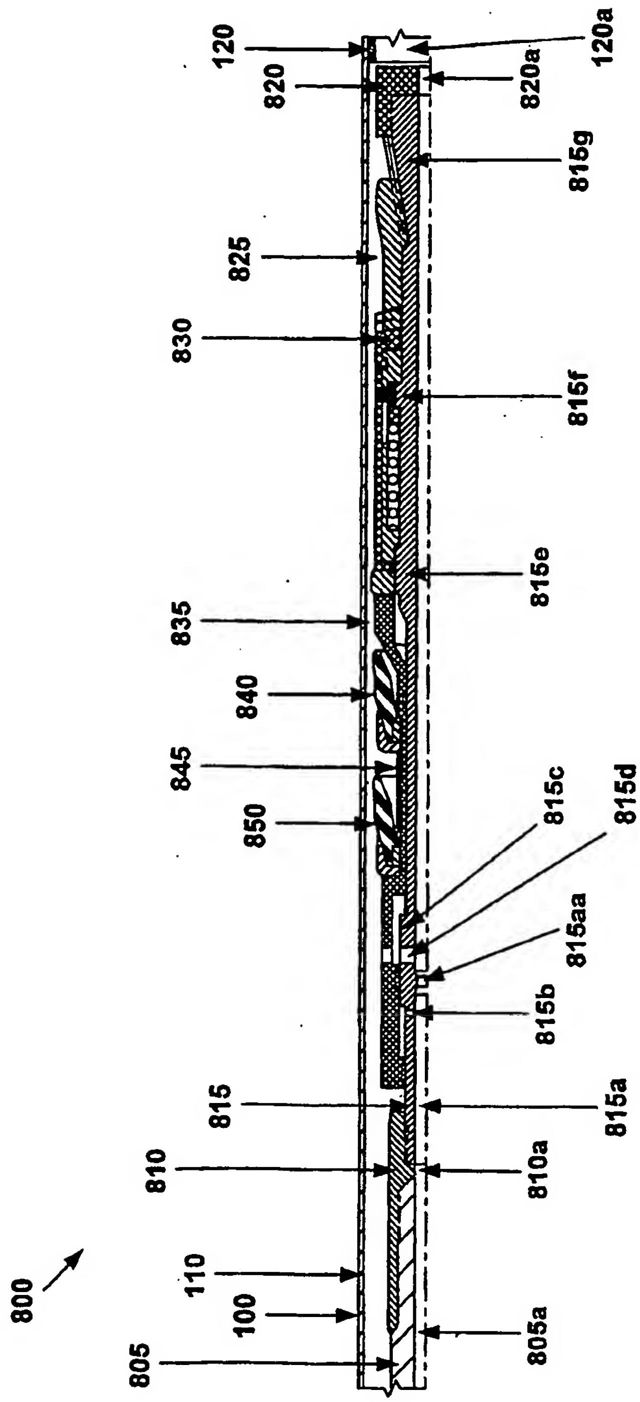


Fig. 14a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805
100
110
810
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850
845
840
835
830
825
820
120
120a
820a
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815f
815e
815c
815d
815aa
815b
815a
810a
805a

Fig. 15

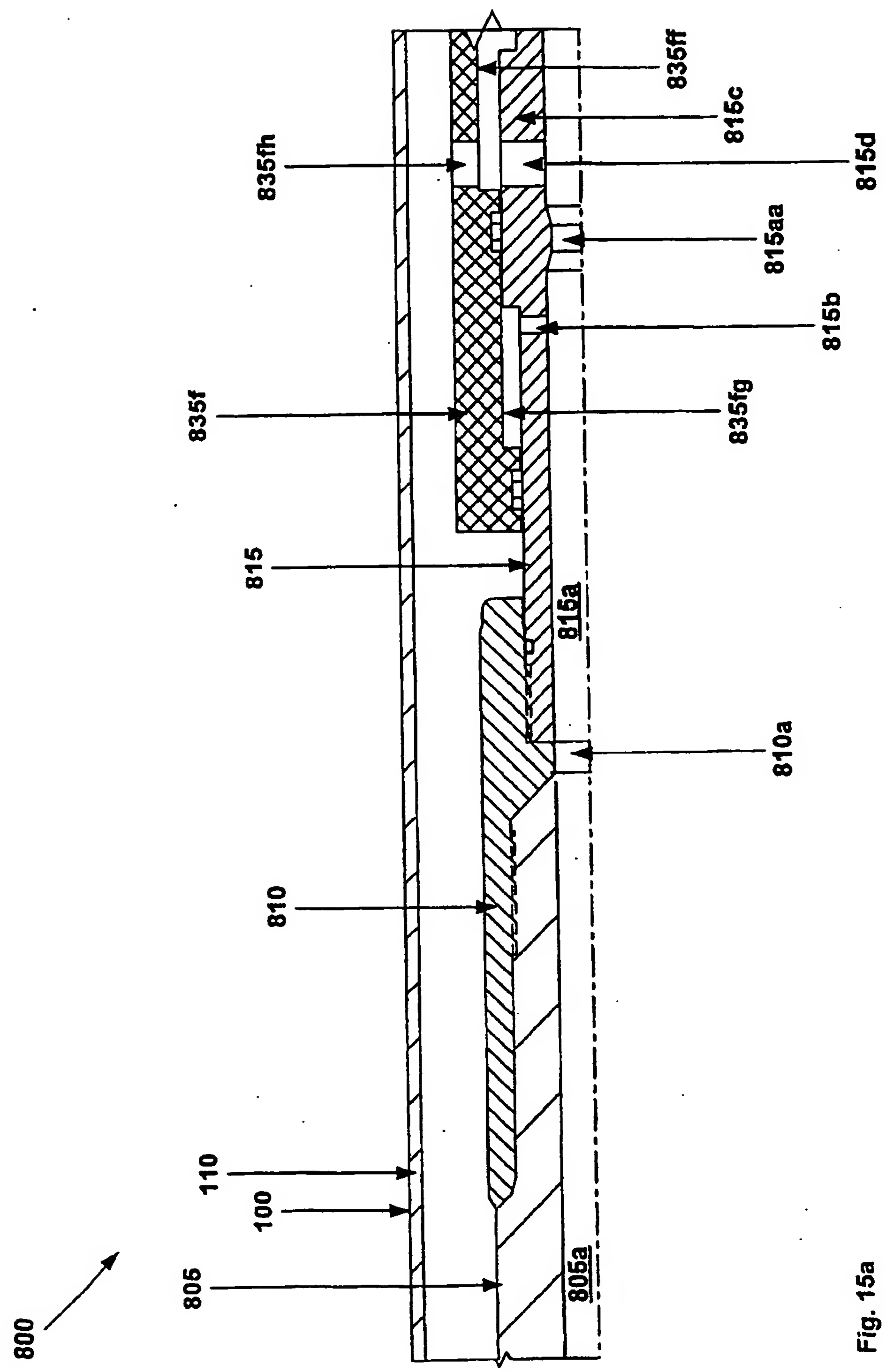
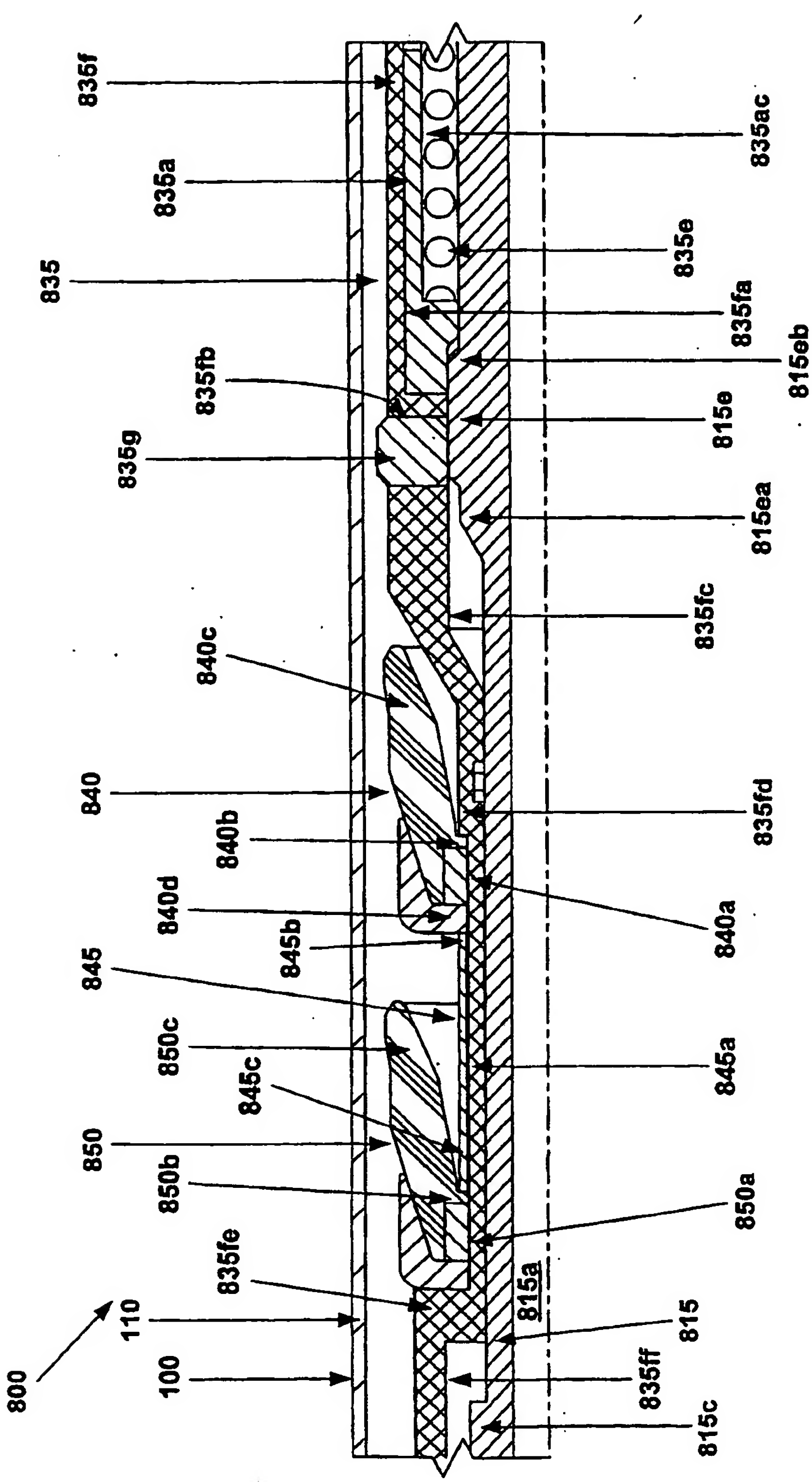
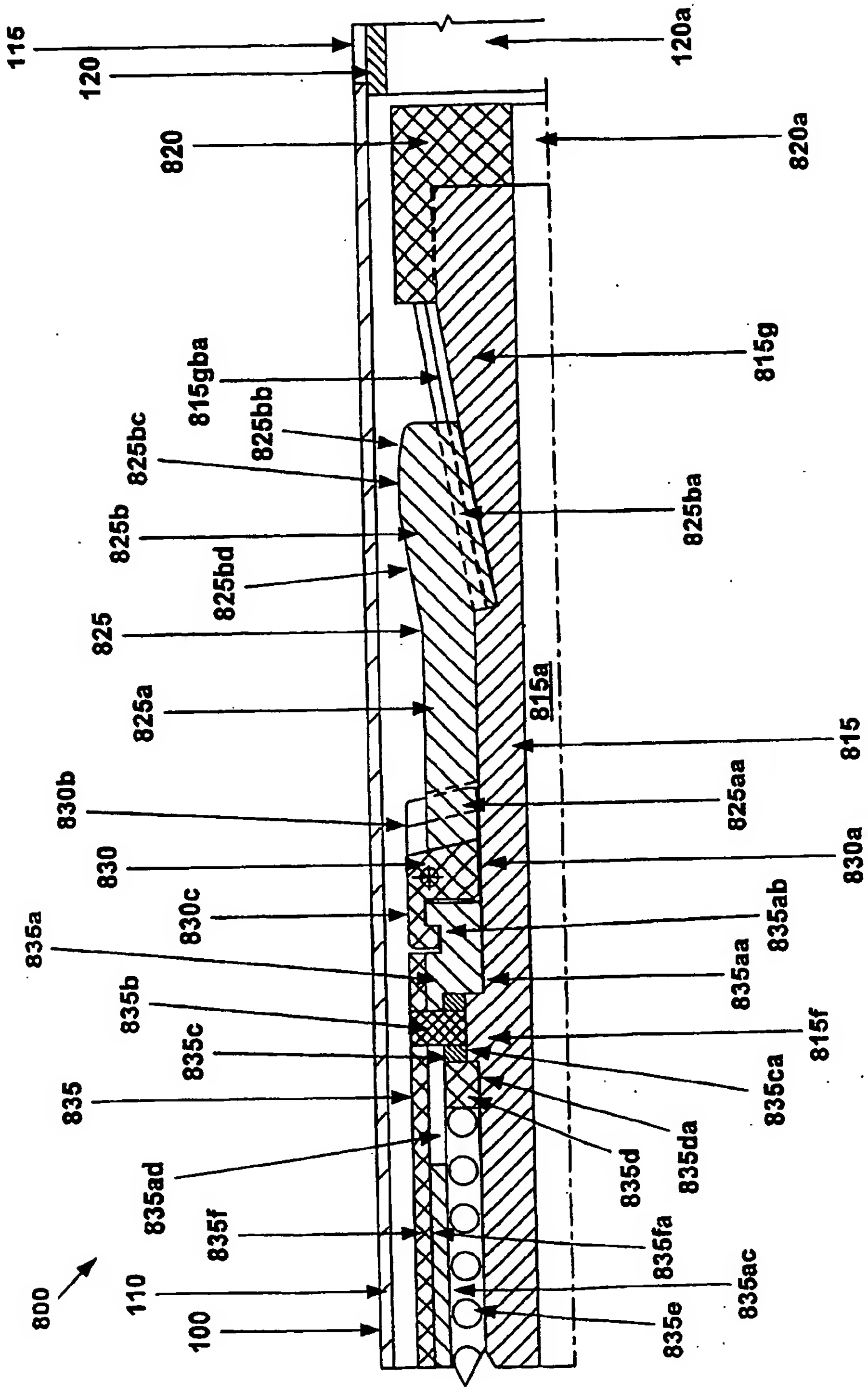

800
805
805a
100
110
810
810a
815
815a
835f
835fg
815b
815aa
835fh
815d
815c
835ff

Fig. 15a



835f
835a
835
835fb
835g
840c
840
840b
840d
845b
845
850c
845c
850
850b
835fe
110
100
800
835ac
835e
835fa
815eb
815e
815ea
835fc
835fd
840a
845a
850a
815a
815
835ff
815c

Fig. 15b


115
120
120a
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820a
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815gba
825bb
825bc
825ba
825b
825bd
825
815a
825a
815
830b
825aa
830
830a
830c
835ab
835a
835aa
835b
815f
835c
835ca
835
835d
835da
835ad
835f
835fa
800
110
835ac
100
835e

Fig. 15c

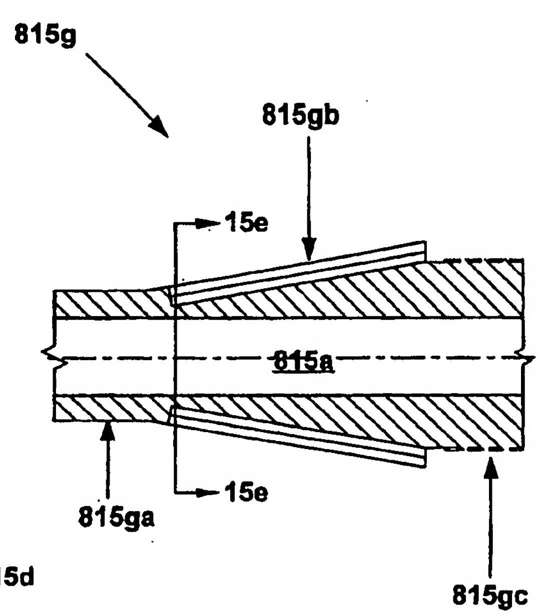


Fig. 15d

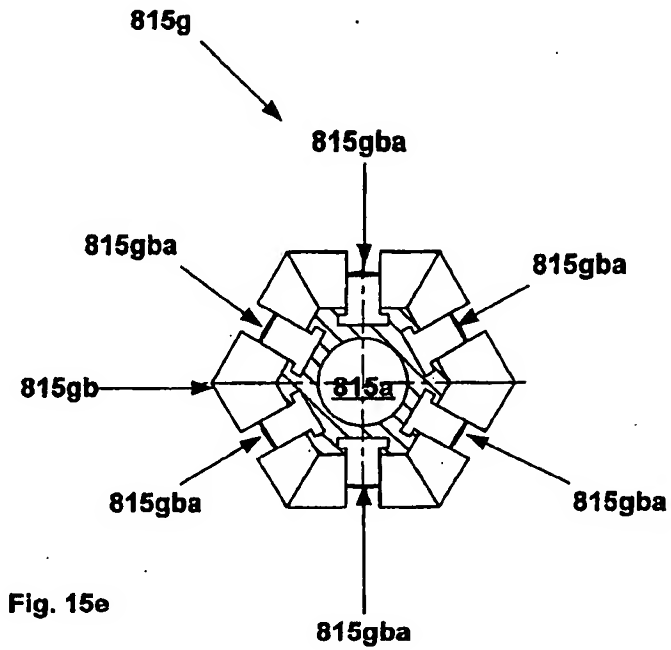


Fig. 15e

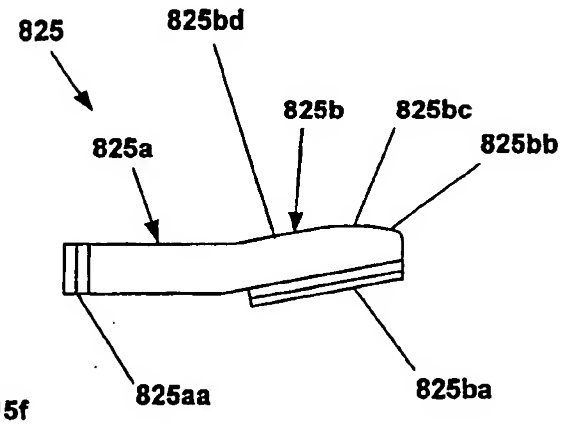


Fig. 15f

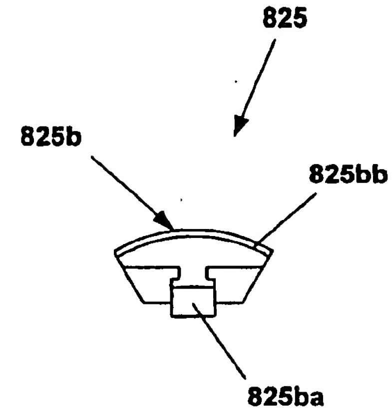


Fig. 15g

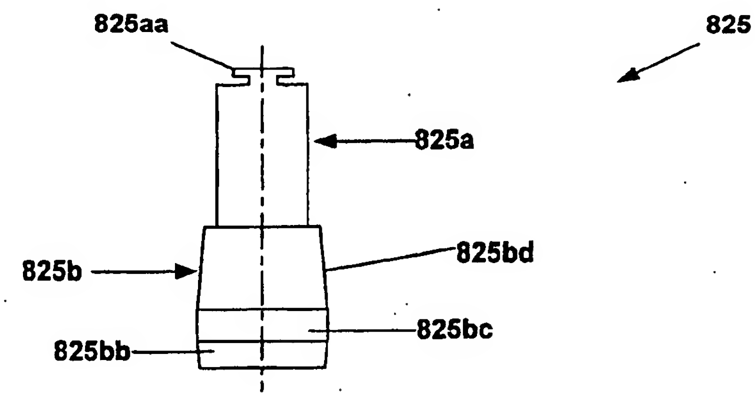
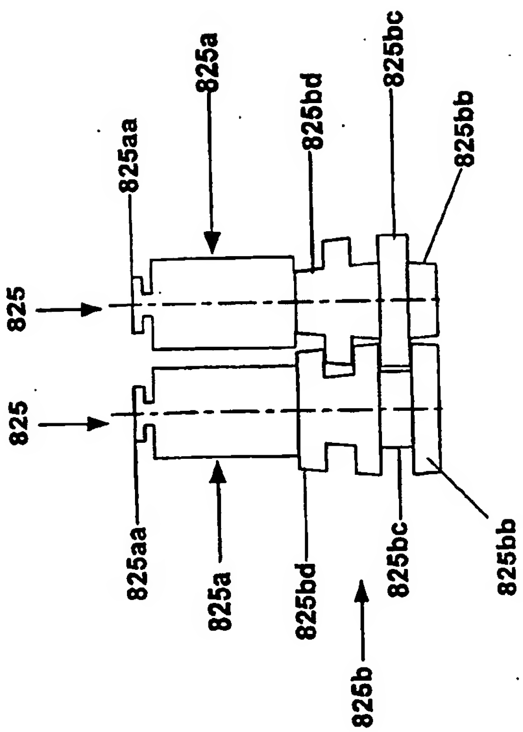


Fig. 15h



825
825
825aa
825a
825bd
825bc
825bb
825aa
825a
825bd
825bc
825bb
825b

Fig. 15i

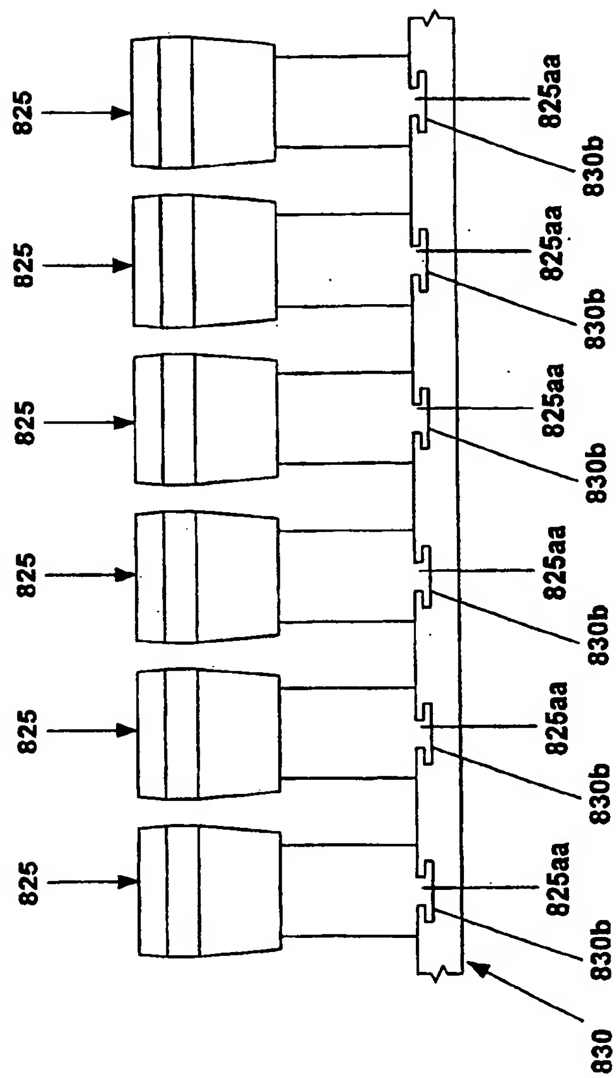
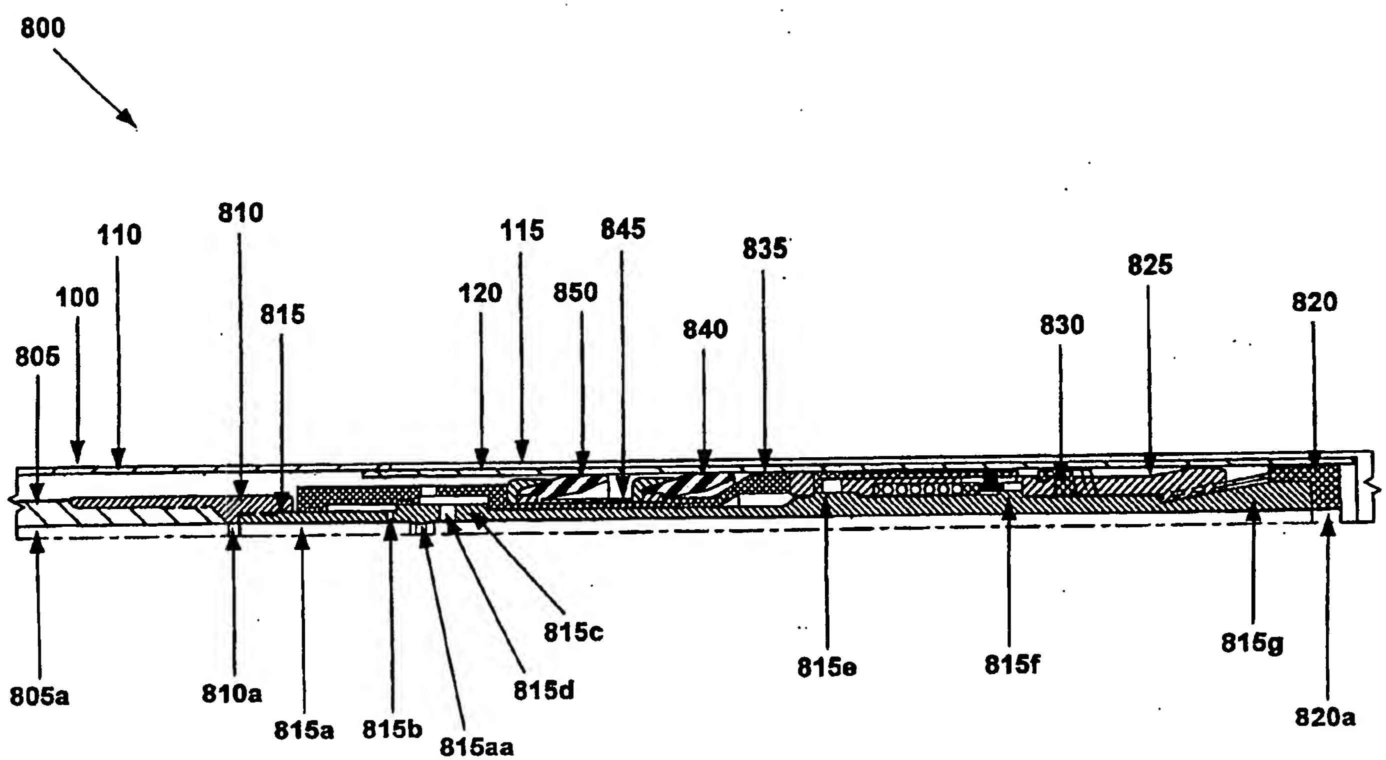

825
825
825
825
825
825
825aa
825aa
825aa
825aa
825aa
825aa
830b
830b
830b
830b
830b
830b
830

Fig. 15j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110
810
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120
115
850
845
840
835
830
825
820
805a
810a
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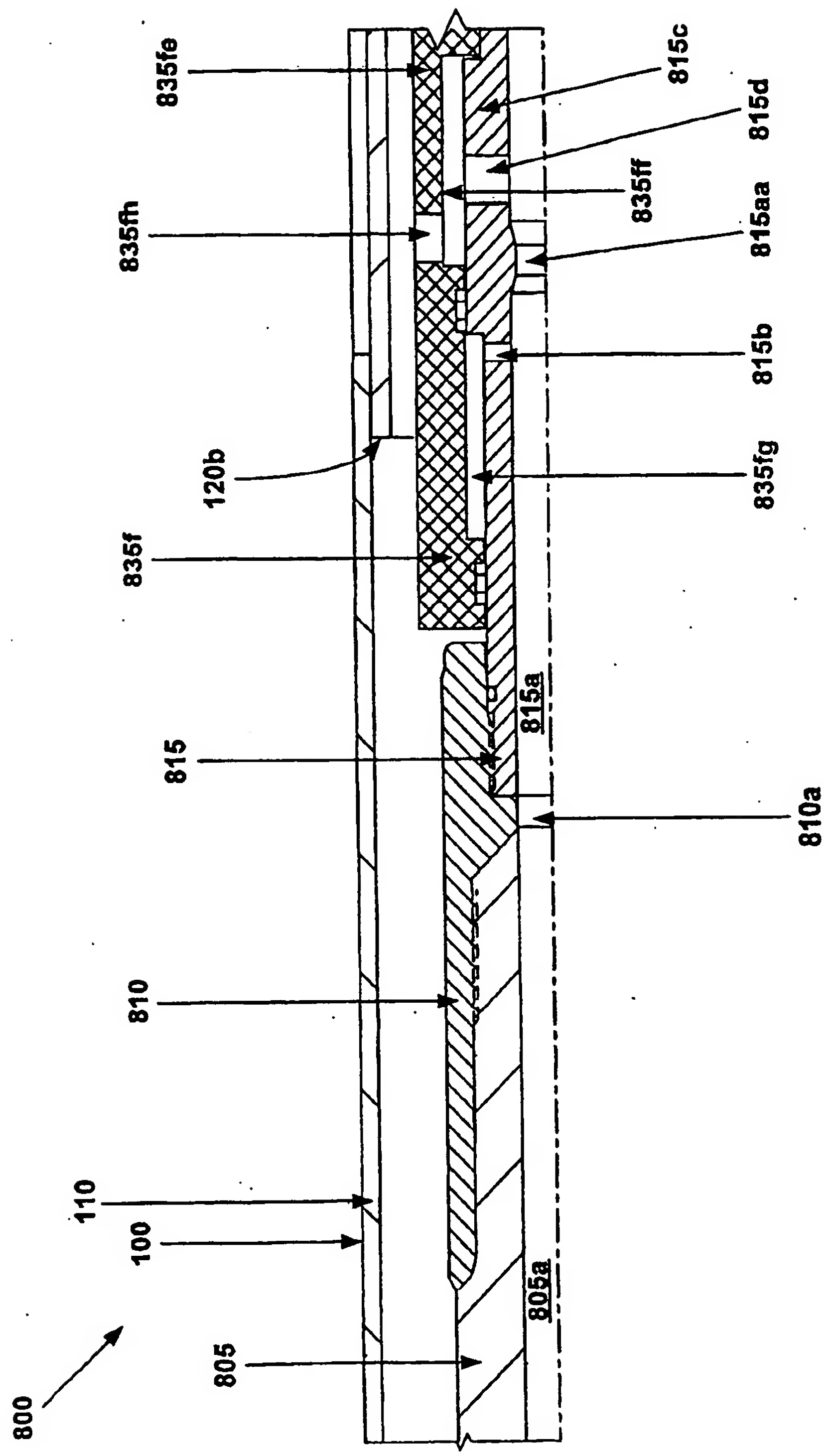
815b
815aa
815d
815c
815e
815f
815g
820a

Fig. 16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805
805a
100
110
810
810a
815
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120b
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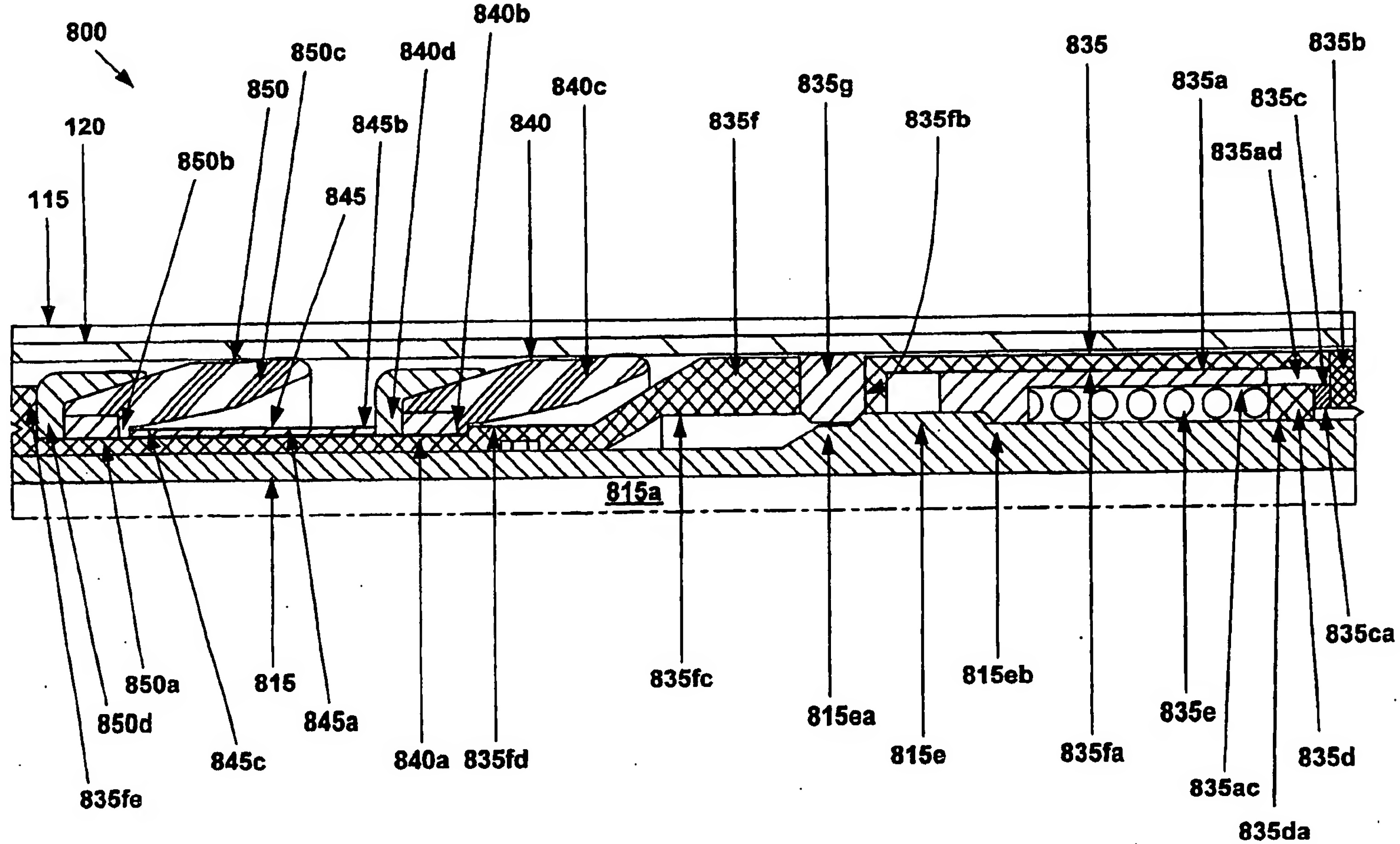
835fh
815aa
835ff
815d
835fe
815c

Fig. 16a


800
115
120
850b
850
850c
845
845b
840d
840b
840
840c
835f
835g
835fb
835
835a
835ad
835c
835b
815a
835fe
850d
850a
845c
815
845a
840a
835fd
835fc
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815eb
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835e
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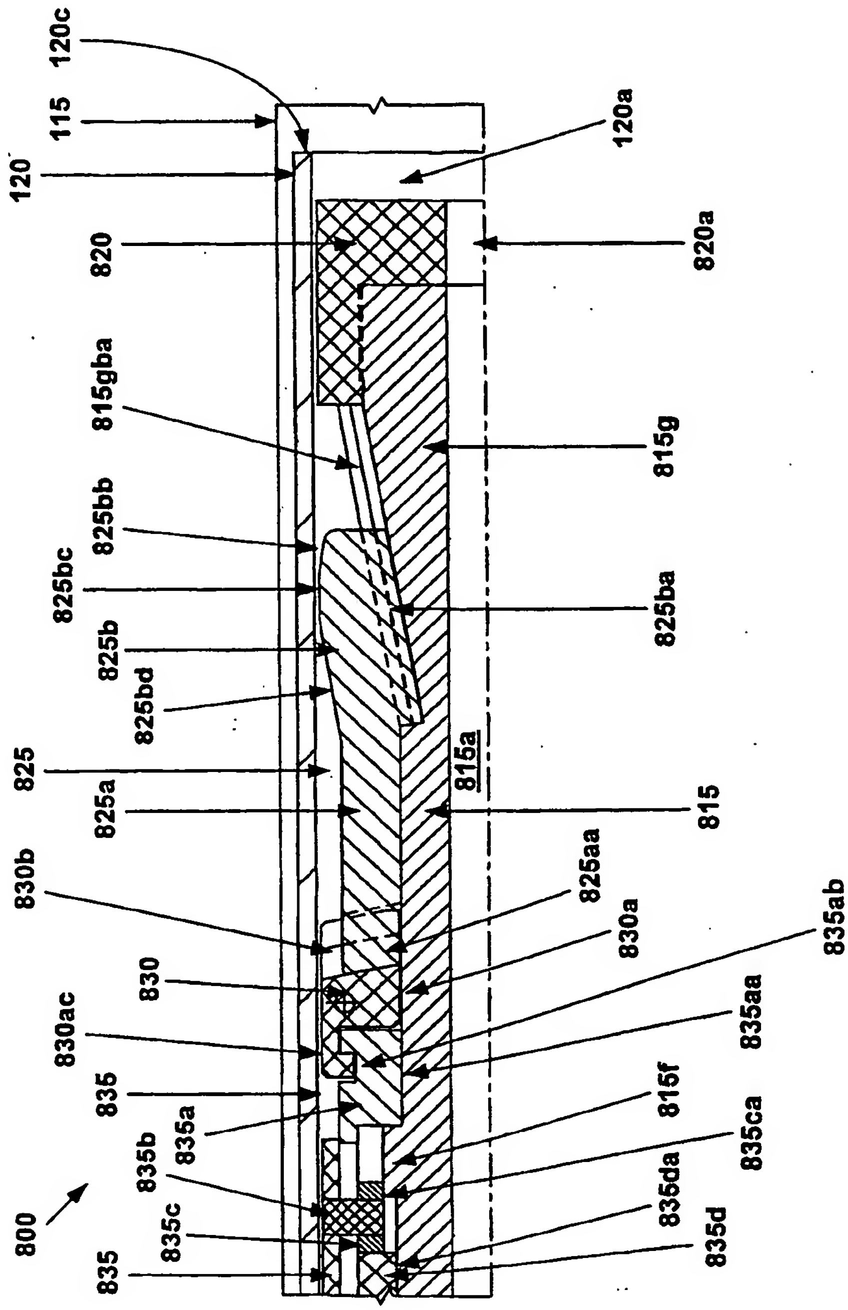
835d
835ca

Fig. 16b


120c
115
120
120a
820
820a
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815g
825bb
825bc
825ba
825b
825bd
825
815a
825a
815
830b
825aa
830a
830
835ab
830ac
835aa
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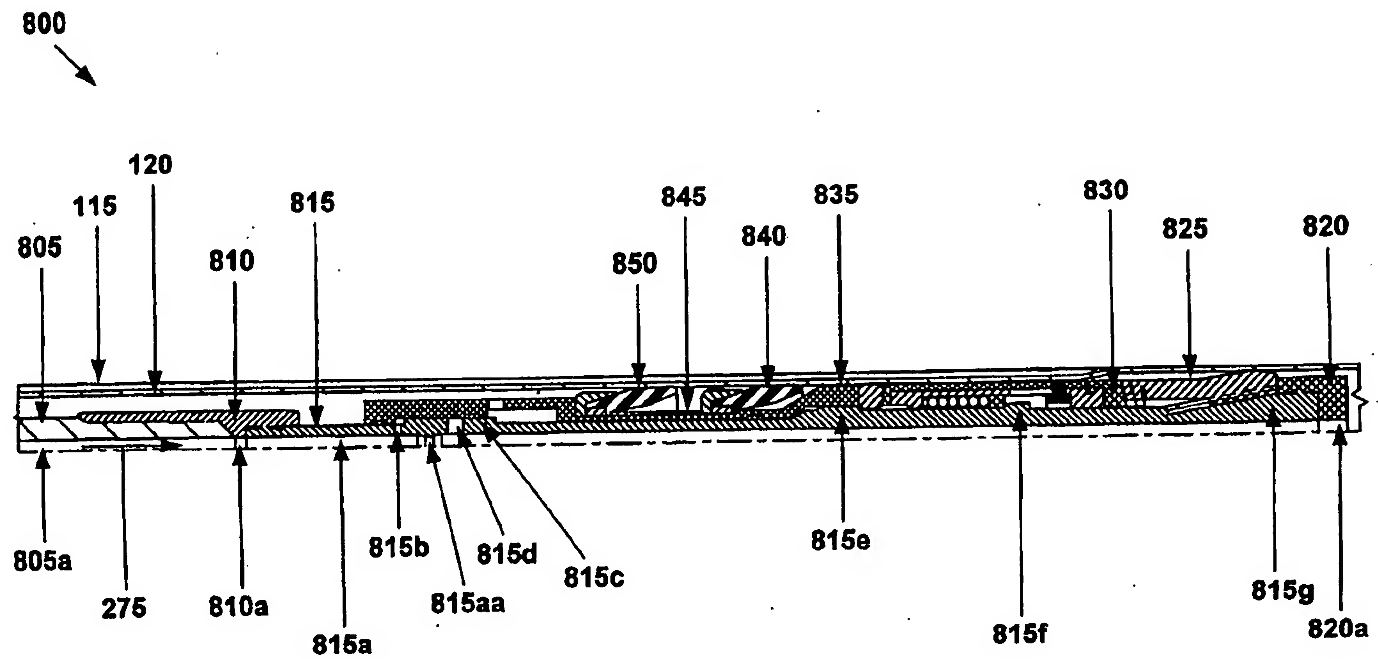
815f
835a
835b
835ca
835da
800
835c
835d
835

Fig. 16c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805
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120
810
815
850
845
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835
830
825
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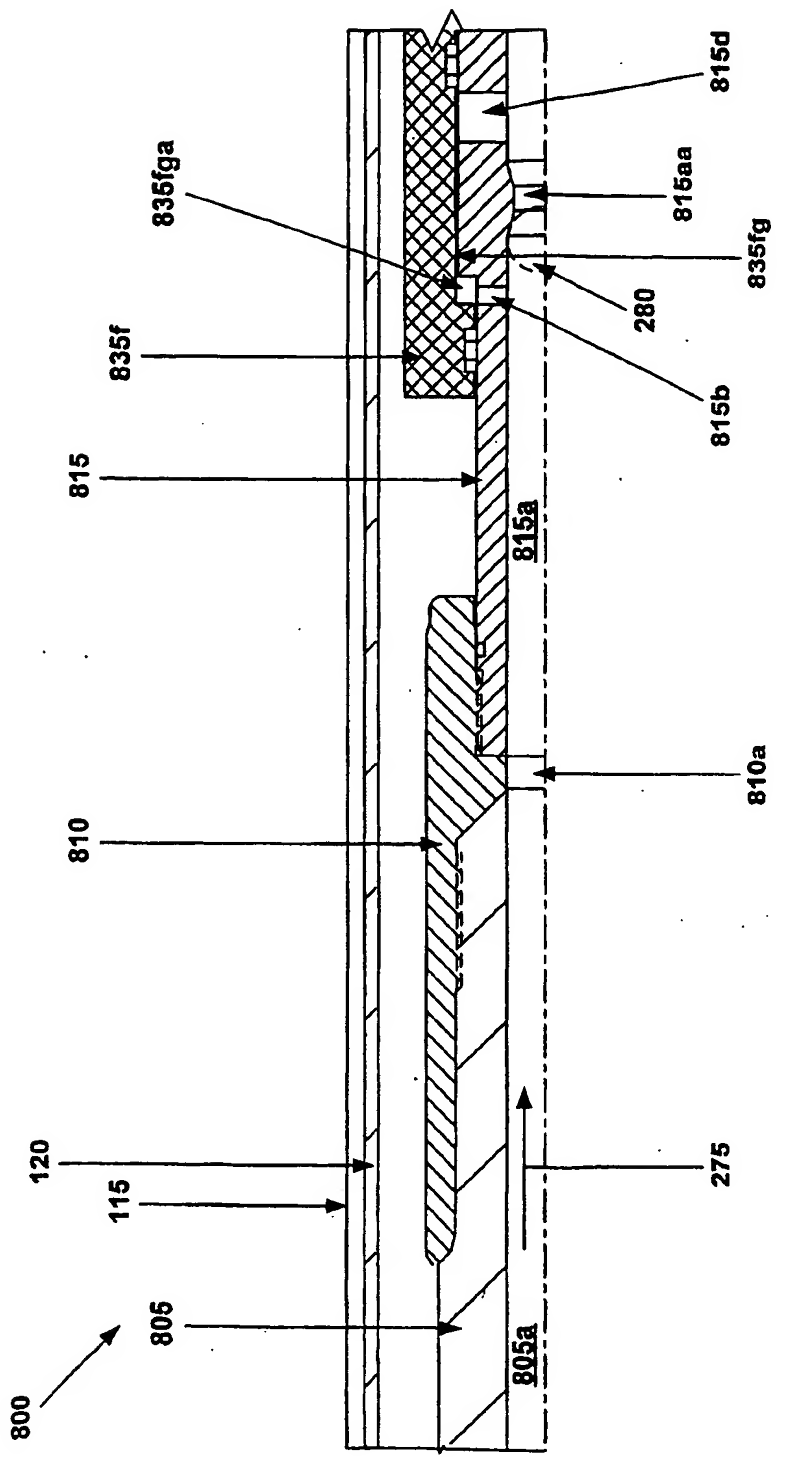
815c
815e
815f
815g
820a

Fig. 17


800
805
805a
115
120
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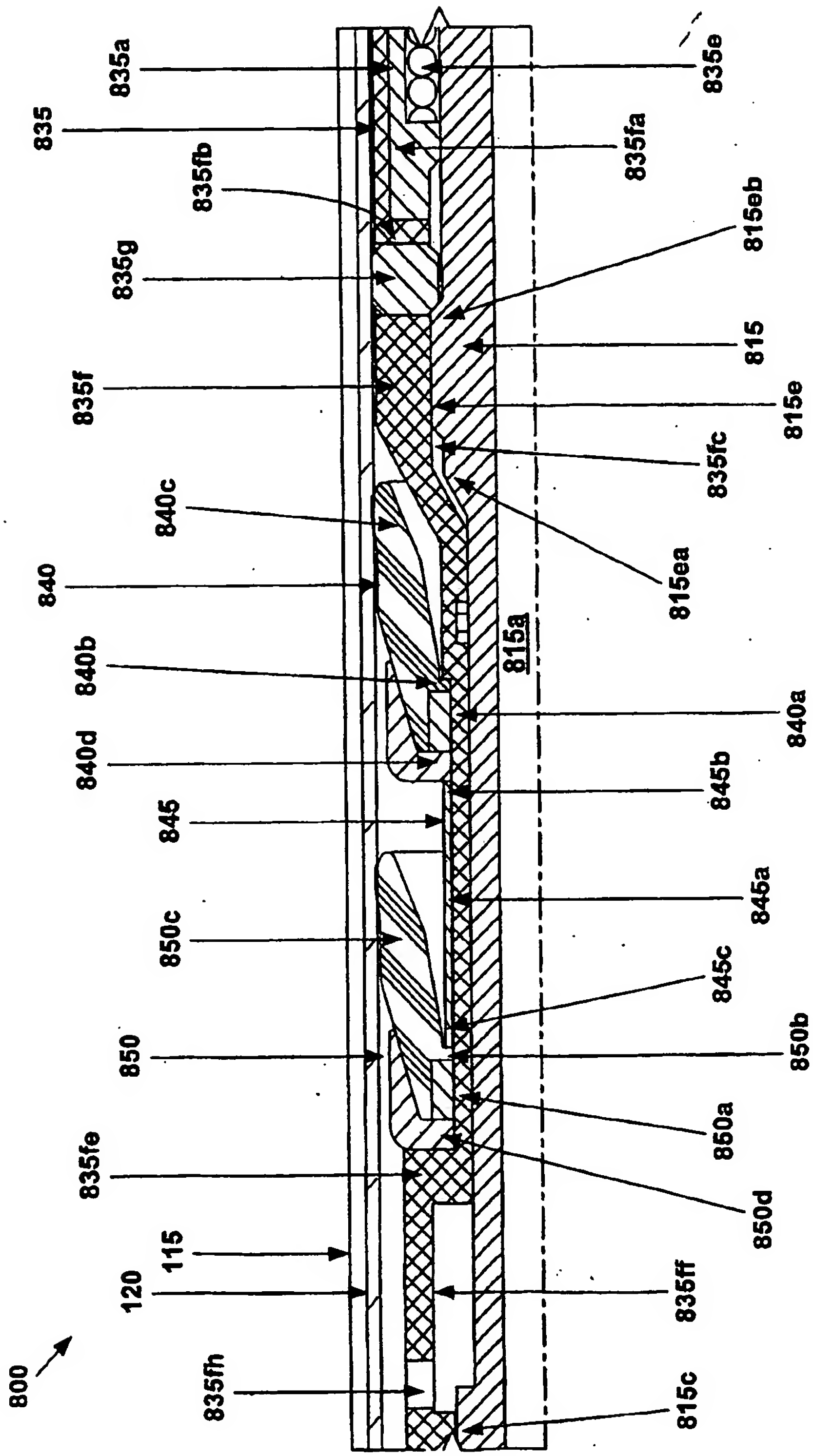
810
810a
815
815a
835f
815b
835fga
280
835fg
815aa
815d

Fig. 17a


800
835a
835
835fb
835g
835f
840c
840
840b
840d
845
850c
850
835fe
115
120
835fh
835e
835fa
815eb
815
815e
835fc
815ea
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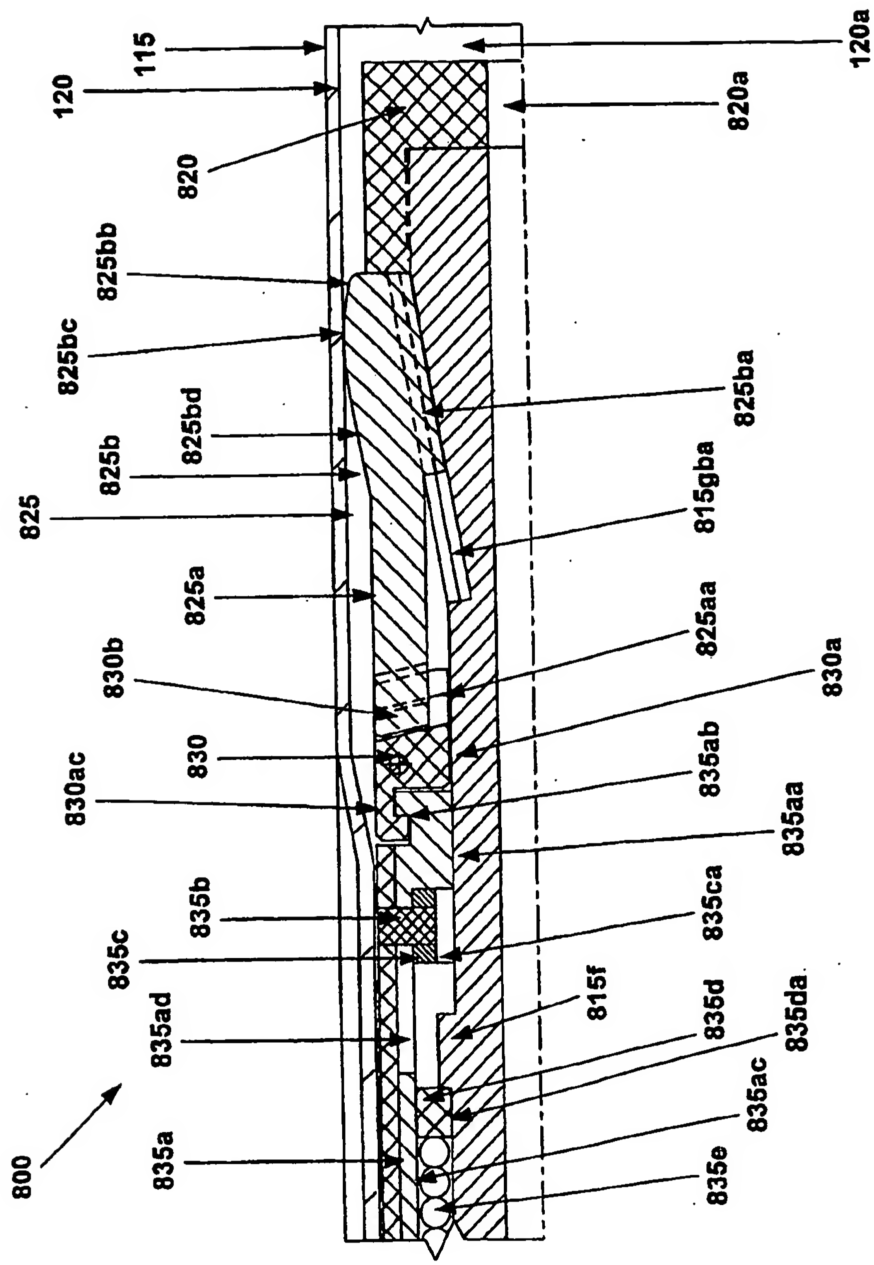
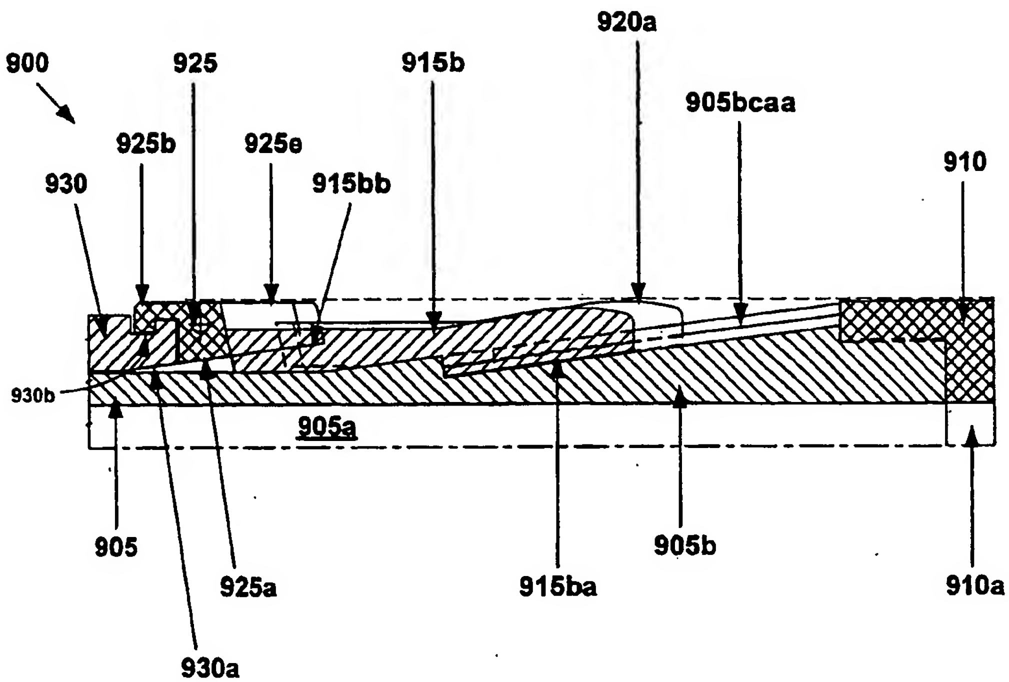
840a
845b
845a
845c
850b
850a
850d
835ff
815c

Fig. 17b



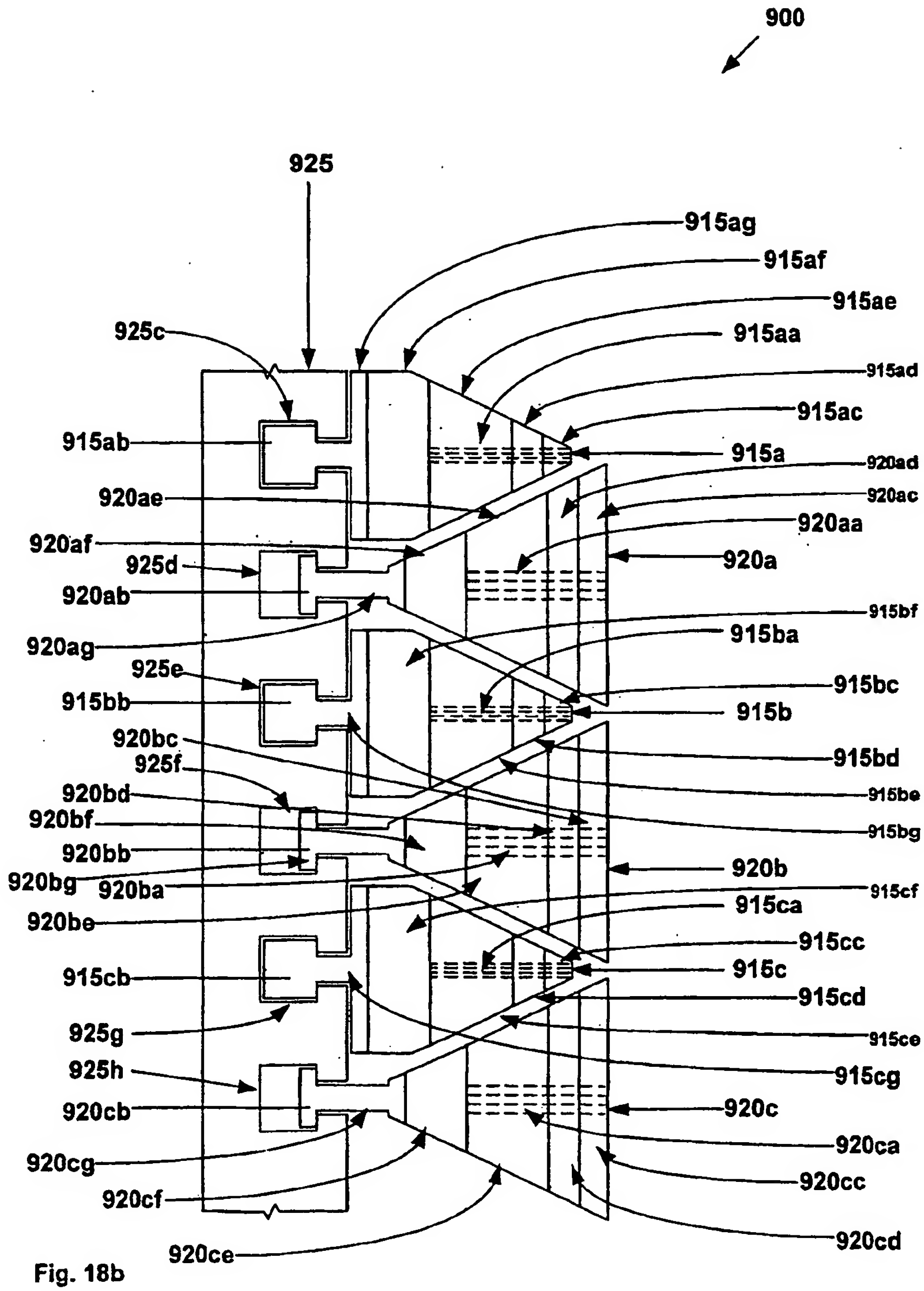
800
835a
835ad
835c
835b
830ac
830
830b
825a
825
825b
825bd
825bc
825bb
820
120
115
120a
820a
825ba
815gba
825aa
830a
835ab
835aa
835ca
815f
835d
835da
835ac
835e

Fig. 17c



900
925
915b
920a
905bcaa
925b
925e
930
915bb
910
930b
905a
905
925a
915ba
905b
910a
930a

Fig. 18a



900
925
915ag
915af
915ae
925c
915aa
915ad
915ac
915ab
915a
920ad
920ae
920ac
920aa
920af
925d
920a
920ab
915bf
920ag
915ba
925e
915bc
915bb
915b
920bc
925f
915bd
920bd
915be
920bf
915bg
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915cf
920be
915ca
915cc
915cb
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920ca
920cf
920cc
920cd
920ce

Fig. 18b

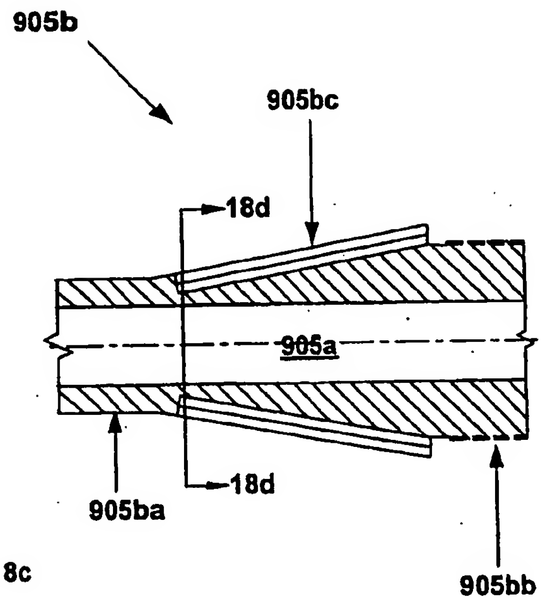


Fig. 18c

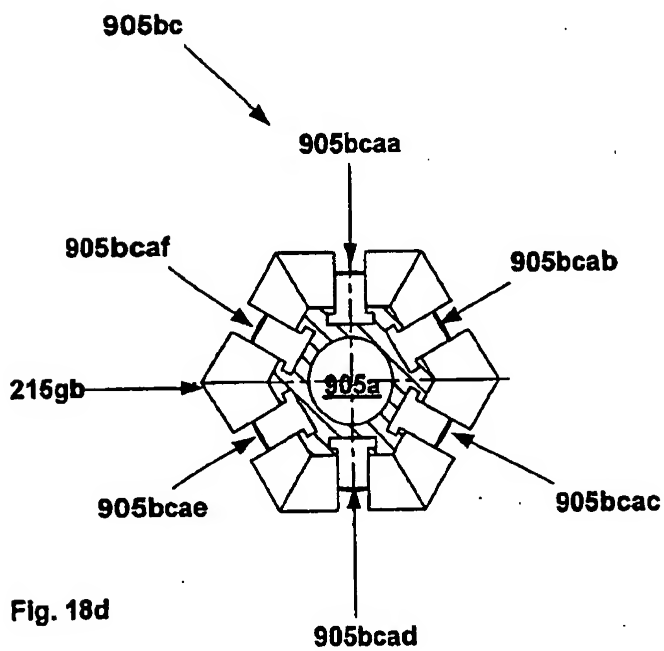
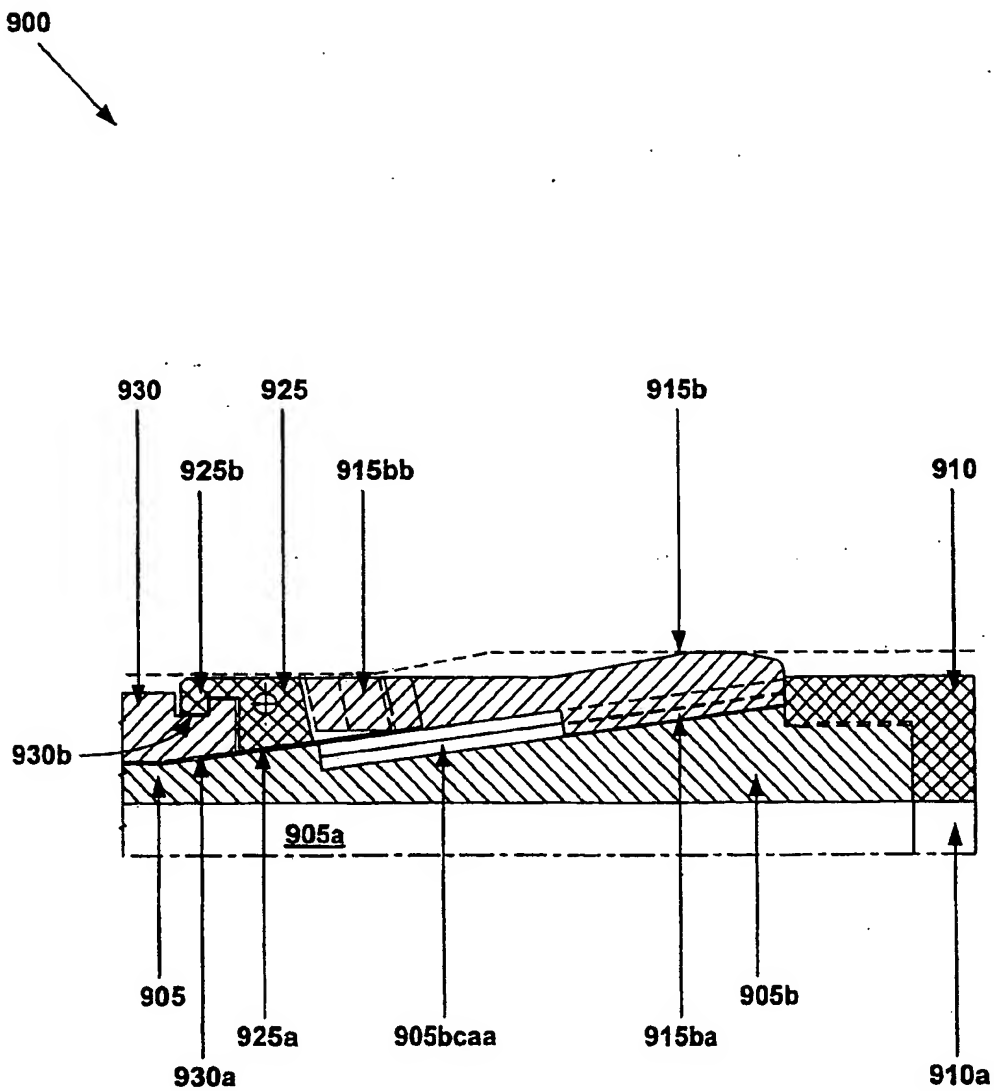


Fig. 18d


900
930
925
915b
925b
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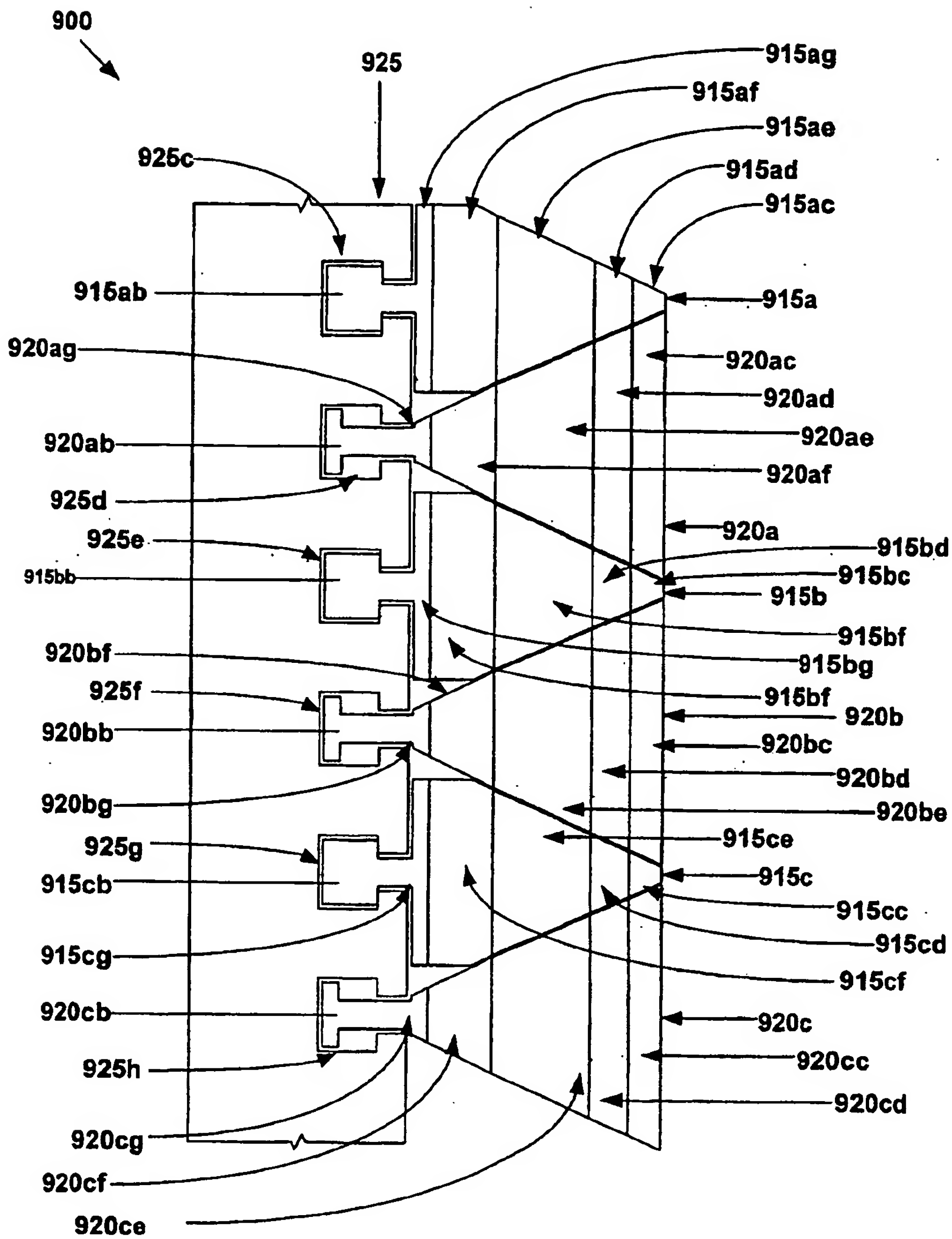
910
930b
905a
905
930a
925a
905bcaa
915ba
905b
910a

Fig. 19a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920ad
920ae
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925d
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925e
915bd
915bb
915bc
915b
915bf
920bf
915bg
925f
915bf
920b
920bb
920bc
920bd
920bg
920be
925g
915ce
915cb
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915cc
915cg
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915cf
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920c
925h
920cc
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920cg
920cf
920ce

Fig. 19b

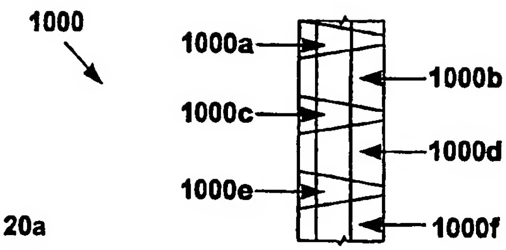

Fig. 20a

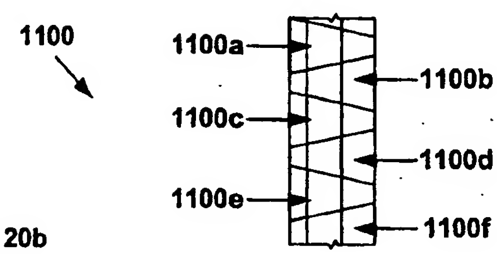

Fig. 20b

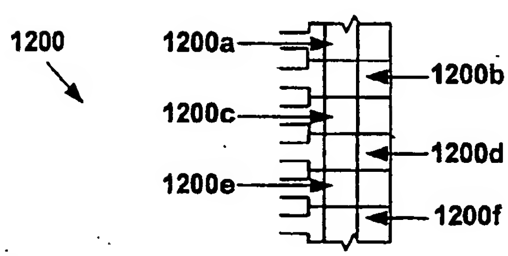

Fig. 20c

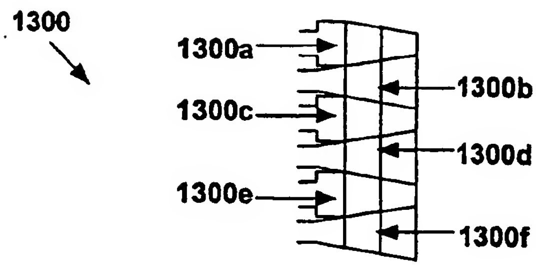

Fig. 20d

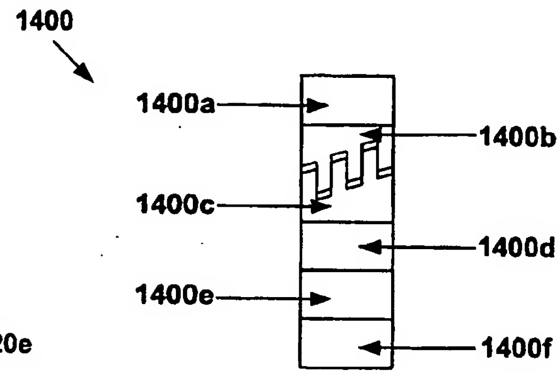

Fig. 20e

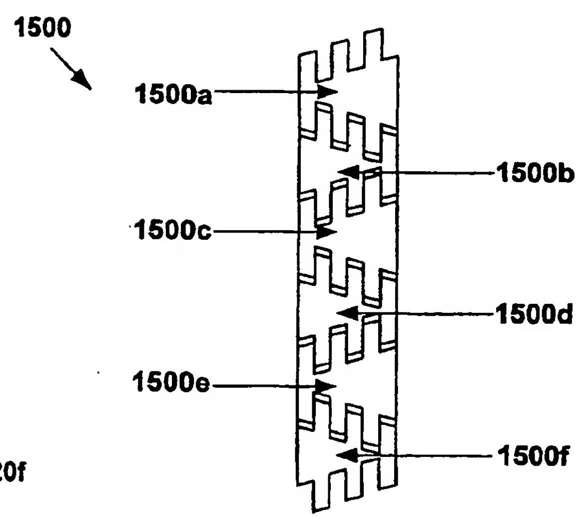

Fig. 20f

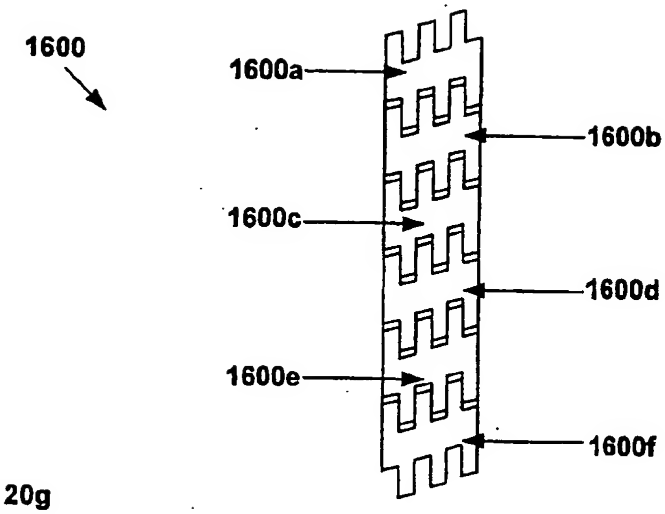

Fig. 20g

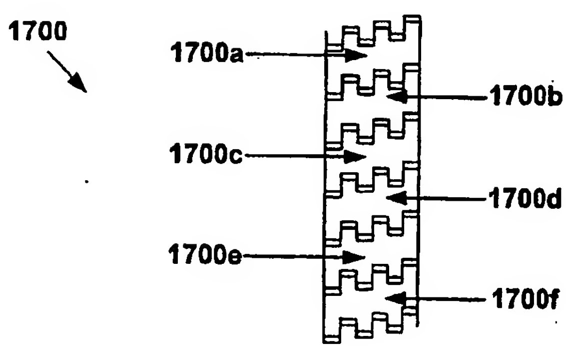

Fig. 20h

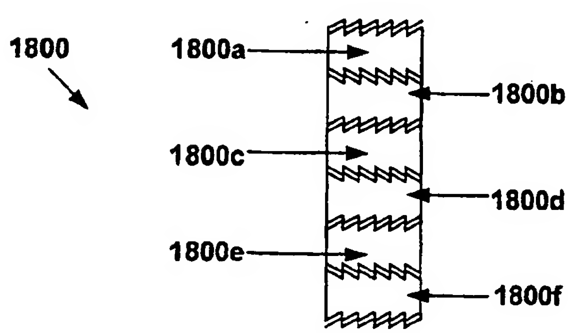

Fig. 20i

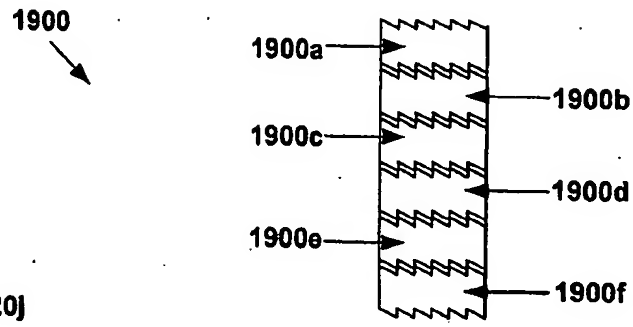

Fig. 20j

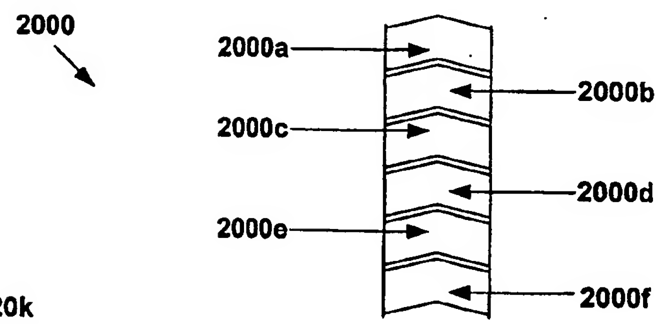

Fig. 20k

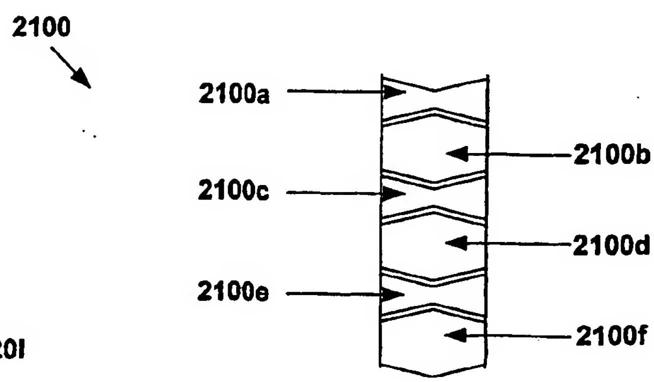

Fig. 20l

2200

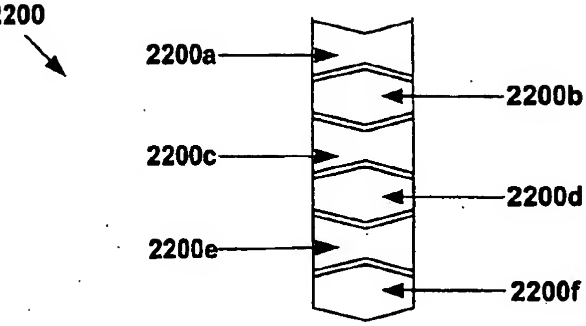

Fig. 20m

ADJUSTABLE EXPANSION CONE ASSEMBLY

Cross Reference To Related Applications

This application claims the benefit of the filing date of U.S. provisional patent application serial no. 60/318,021, attorney docket no. 25791.58, filed on 9/7/2001, the disclosure of which is incorporated herein by reference.

This application is related to the following: (1) U.S. patent application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, (2) U.S. patent application serial no. 09/510,913, attorney docket no. 25791.7.02, filed on 2/23/2000, (3) U.S. patent application serial no. 09/502,350, attorney docket no. 25791.8.02, filed on 2/10/2000, (4) U.S. patent application serial no. 09/440,338, attorney docket no. 25791.9.02, filed on 11/15/1999, (5) U.S. patent application serial no. 09/523,460, attorney docket no. 25791.11.02, filed on 3/10/2000, (6) U.S. patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, (7) U.S. patent application serial no. 09/511,941, attorney docket no. 25791.16.02, filed on 2/24/2000, (8) U.S. patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, (9) U.S. patent application serial no. 09/559,122, attorney docket no. 25791.23.02, filed on 4/26/2000, (10) PCT patent application serial no. PCT/US00/18635, attorney docket no. 25791.25.02, filed on 7/9/2000, (11) U.S. provisional patent application serial no. 60/162,671, attorney docket no. 25791.27, filed on 11/1/1999, (12) U.S. provisional patent application serial no. 60/154,047, attorney docket no. 25791.29, filed on 9/16/1999, (13) U.S. provisional patent application serial no. 60/159,082, attorney docket no. 25791.34, filed on 10/12/1999, (14) U.S. provisional patent application serial no. 60/159,039, attorney docket no. 25791.36, filed on 10/12/1999, (15) U.S. provisional patent application serial no. 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999, (16) U.S. provisional patent application serial no. 60/212,359, attorney docket no. 25791.38, filed on 6/19/2000, (17) U.S. provisional patent application serial no. 60/165,228, attorney docket no. 25791.39, filed on 11/12/1999, (18) U.S. provisional patent application serial no. 60/221,443, attorney docket no. 25791.45, filed on 7/28/2000, (19) U.S. provisional patent application serial no. 60/221,645, attorney docket no. 25791.46, filed on 7/28/2000, (20) U.S. provisional patent application serial no. 60/233,638, attorney docket no. 25791.47, filed on 9/18/2000, (21) U.S. provisional patent application serial no. 60/237,334, attorney docket no. 25791.48, filed on 10/2/2000, (22) U.S. provisional patent application serial no. 60/270,007, attorney docket no. 25791.50, filed on 2/20/2001; and (23) U.S. provisional patent application serial no. 60/262,434, attorney docket no. 25791.51, filed on 1/17/2001, the disclosures of which are incorporated herein by reference.

Background of the Invention

This invention relates generally to wellbore casings, and in particular to wellbore casings that are formed using expandable tubing.

Conventionally, when a wellbore is created, a number of casings are installed in the borehole to prevent collapse of the borehole wall and to prevent undesired outflow of drilling fluid into the formation or inflow of fluid from the formation into the borehole. The borehole is drilled in intervals whereby a casing which is to be installed in a lower borehole interval is lowered through a previously installed casing of an upper borehole interval. As a consequence of this procedure the casing of the lower interval is of smaller diameter than the casing of the upper interval. Thus, the casings are in a nested arrangement with casing diameters decreasing in downward direction. Cement annuli are provided between the outer surfaces of the casings and the borehole wall to seal the casings from the borehole wall. As a consequence of this nested arrangement a relatively large borehole diameter is required at the upper part of the wellbore. Such a large borehole diameter involves increased costs due to heavy casing handling equipment, large drill bits and increased volumes of drilling fluid and drill cuttings. Moreover, increased drilling rig time is involved due to required cement pumping, cement hardening, required equipment changes due to large variations in hole diameters drilled in the course of the well, and the large volume of cuttings drilled and removed.

The present invention is directed to overcoming one or more of the limitations of the existing procedures for forming new sections of casing in a wellbore.

Summary of the Invention

According to one aspect of the present invention, an apparatus for radially expanding a tubular member is provided that includes a tubular support member that includes a first tubular support body defining a longitudinal passage, a first lug coupled to and extending from the first tubular support body in the radial direction, a second lug coupled to and extending from the first tubular support body in the radial direction, and an expansion cone support body coupled to the first tubular support body. The expansion cone support body includes an N-sided tapered tubular support member, wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot. N expansion cone segments are movably coupled to the expansion cone support body, each including an expansion cone segment body including arcuate conical outer surfaces, a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body, and a

second T-shaped retaining member coupled to the expansion cone segment body. A split ring collar assembly is movably coupled to the exterior of the tubular support member that includes a second tubular support body defining N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments, and an L-shaped retaining member coupled to the second tubular support body. A first drag block assembly is movably coupled to the tubular support member that includes a first drag block body defining a slot for receiving and mating with the L-shaped retaining member of the split ring collar, and a first J-shaped slot for receiving the first lug, and one or more first drag blocks coupled to the first drag block body. A second drag block assembly is movably coupled to the tubular support member that includes a second drag block body defining a second J-shaped slot for receiving the second lug, and one or more second drag blocks coupled to the second drag block body. First and second packer cups are coupled to the tubular support member between the first and second drag block assemblies.

According to another aspect of the present invention, an apparatus for radially expanding a tubular member is provided that includes a tubular support member that includes a first tubular support body defining a longitudinal passage, a first flange coupled to the first tubular support body, a second flange coupled to the first tubular support body, a first tapered flange coupled to the first tubular support body, a second tapered flange coupled to the first tubular support body, and an expansion cone support body coupled to the first tubular support body. The expansion cone support body includes an N-sided tapered tubular support member, wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot. N expansion cone segments are movably coupled to the expansion cone support body, each including an expansion cone segment body including arcuate conical outer surfaces, a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body, and a second T-shaped retaining member coupled to the expansion cone segment body. A split ring collar is movably coupled to the exterior of the tubular support member that includes a second tubular support body that defines N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments, and an L-shaped retaining member coupled to the second tubular support body. A first collet assembly is movably coupled to the tubular support member that includes a first tubular sleeve that defines a slot for receiving and mating with the L-shaped retaining member of the split ring collar, a first counterbore for receiving the first flange, and a first radial

passage, a first spring received within the first counterbore, a first retaining ring received within the first counterbore, a first load transfer pin coupled to the first retaining ring and extending through the first radial passage, a second tubular sleeve coupled to the first load transfer pin, a first resilient collet coupled to the second tubular sleeve and positioned above the first tapered flange, and a third tubular sleeve coupled to the first resilient collet. A second collet assembly is movably coupled to the tubular support member that includes a fourth tubular sleeve that defines a second counterbore for receiving the second flange, and a second radial passage, a second spring received within the second counterbore, a second retaining ring received within the second counterbore, a second load transfer pin coupled to the second retaining ring and extending through the second radial passage, a fifth tubular sleeve coupled to the second load transfer pin, a second resilient collet coupled to the fifth tubular sleeve and positioned above the second tapered flange, and a sixth tubular sleeve coupled to the second resilient collet. First and second packer cups coupled to the tubular support member between the first and second collet assemblies.

According to another aspect of the present invention, an apparatus for radially expanding a tubular member is provided that includes a tubular support member that includes a first tubular support body defining a longitudinal passage, a first radial passage defined in the first tubular support body fluidicly coupled to the longitudinal passage, a first flange coupled to the first tubular support body, a second flange coupled to the first tubular support body, a first tapered flange coupled to the first tubular support body, a second tapered flange coupled to the first tubular support body, and an expansion cone support body coupled to the first tubular support body. The expansion cone support body includes an N-sided tapered tubular support member, wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot. N expansion cone segments are movably coupled to the expansion cone support body, each including an expansion cone segment body including arcuate conical outer surfaces, a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body, and a second T-shaped retaining member coupled to the expansion cone segment body. A split ring collar is movably coupled to the exterior of the tubular support member that includes a second tubular support body that defines N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments, and an L-shaped retaining member coupled to the second tubular support body. A first dog assembly is movably coupled to the tubular support

member that includes a first tubular sleeve that defines a slot for receiving and mating with the L-shaped retaining member of the split ring collar, a first counterbore for receiving the first flange, and a second radial passage, a first spring received within the first counterbore, a first retaining ring received within the first counterbore, a first load transfer pin coupled to the first retaining ring and extending through the second radial passage, and a second tubular sleeve coupled to the first load transfer pin that defines a second counterbore for receiving the first tubular sleeve, a first resilient dog coupled to the second tubular sleeve and positioned adjacent to the first tapered flange. A second dog assembly is movably coupled to the tubular support member that includes a third tubular sleeve that defines a second counterbore for receiving the second flange, a third radial passage, and a fourth radial passage fluidicly coupled to the first radial passage, a second spring received within the second counterbore, a second retaining ring received within the second counterbore, a second load transfer pin coupled to the second retaining ring and extending through the third radial passage, a fourth tubular sleeve coupled to the second load transfer pin, and a second resilient dog coupled to the fourth tubular sleeve and positioned adjacent to the second tapered flange. First and second packer cups are coupled to the tubular support member between the first and second dog assemblies.

According to another aspect of the present invention, an apparatus for radially expanding a tubular member is provided that includes a tubular support member that includes a first tubular support body defining a longitudinal passage including a throat passage, a first radial passage defined in the first tubular support body fluidicly coupled to the longitudinal passage, a first flange coupled to the first tubular support body, a second flange coupled to the first tubular support body that defines a second radial passage defined in the second flange fluidicly coupled to the longitudinal passage, a tapered flange coupled to the first tubular support body, and an expansion cone support body coupled to the first tubular support body. The expansion cone support body includes an N-sided tapered tubular support member, wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot. N expansion cone segments are movably coupled to the expansion cone support body, each including an expansion cone segment body including arcuate conical outer surfaces, a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body, and a second T-shaped retaining member coupled to the expansion cone segment body. A split ring collar is movably coupled to the exterior of the tubular support member that includes a second tubular

support body that defines N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments, and an L-shaped retaining member coupled to the second tubular support body. A dog assembly is movably coupled to the tubular support member that includes a first tubular sleeve that defines a slot for receiving and mating with the L-shaped retaining member of the split ring collar, a first counterbore for receiving the first flange, and a third radial passage, a spring received within the first counterbore, a retaining ring received within the first counterbore, a load transfer pin coupled to the retaining ring and extending through the third radial passage, a second tubular sleeve coupled to the first load transfer pin that defines a first counterbore for receiving the first tubular sleeve, a second counterbore for receiving and mating with the tapered flange, and includes a third flange that defines a third counterbore for receiving the second flange, a fourth counterbore for receiving the second flange, and a fourth radial passage, and a resilient dog coupled to the second tubular sleeve and positioned adjacent to the tapered flange. First and second packer cups are coupled to the tubular support member between the resilient dog and the third flange.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a tubular support member that includes a tubular support body and an expansion cone support body coupled to the tubular support body. The expansion cone support body includes an N-sided tapered tubular support member, wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot. N expansion cone segments are movably coupled to the expansion cone support body, each including an expansion cone segment body including arcuate conical outer surfaces, a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body, and a second T-shaped retaining member coupled to the expansion cone segment body. A split ring collar is movably coupled to the exterior of the tubular support member that includes a second tubular support body that defines N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments, and an L-shaped retaining member coupled to the second tubular support body. A tubular actuating sleeve is movably coupled to the tubular support member that includes a third tubular support body that defines a slot for receiving and mating with the L-shaped retaining member of the split ring collar.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a tubular support member that includes a first tubular support body, and an expansion cone support body coupled to the tubular support body. The expansion cone support body includes a tapered tubular support member defining N stepped slots. An expansion cone assembly is movably coupled to the tubular support member that includes a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot, and N expansion cone segments extending from the second tubular support member. Each expansion cone segment includes a resilient collet coupled to the second tubular support member, an expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces, and a retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the stepped slots of the expansion cone support body. A split ring collar is movably coupled to the exterior of the tubular support member that includes a third tubular support body, a first L-shaped retaining member coupled to the third tubular support body for mating with the L-shaped slot of the second tubular support body of the expansion cone assembly, and a second L-shaped retaining member coupled to the third tubular body. A tubular actuating sleeve is movably coupled to the tubular support member that includes a third tubular support body that defines a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a tubular support member that includes a first tubular support body, and an expansion cone support body coupled to the tubular support body. The expansion cone support body includes a tapered tubular support member defining N slots. An expansion cone assembly is movably coupled to the tubular support member that includes a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot, and N expansion cone segments extending from the second tubular support member. Each expansion cone segment includes a resilient collet coupled to the second tubular support member, an expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces, and a retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body. A split ring collar is movably coupled to the exterior of the tubular support member that includes a third tubular support body, a first L-shaped retaining member coupled to the third tubular support body for mating with

the L-shaped slot of the second tubular support body, and a second L-shaped retaining member coupled to the third tubular support body. A tubular actuating sleeve is movably coupled to the tubular support member that includes a third tubular support body that defines a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a tubular support member that includes a first tubular support body, and an expansion cone support body coupled to the tubular support body. The expansion cone support body includes a tapered tubular support member defining N slots. An expansion cone assembly is movably coupled to the tubular support member that includes a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot, N/2 first expansion cone segments extending from the second tubular support member, and N/2 second expansion cone segments extending from the second tubular member. Each first expansion cone segment includes a first resilient collet coupled to the second tubular support member, a first expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces, and a first retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body. Each second expansion cone segment includes a second resilient collet coupled to the second tubular support member, a second expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces, and a second retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body. The second expansion cone segments overlap and are interleaved with the first expansion cone segments. A split ring collar is movably coupled to the exterior of the tubular support member that includes a third tubular support body, a first L-shaped retaining member coupled to the third tubular support body for mating with L-shaped slot of the second tubular support body, and a second L-shaped retaining member coupled to the third tubular support body. A tubular actuating sleeve is movably coupled to the tubular support member that includes a third tubular support body that defines a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a tubular support member that includes a first tubular support body, and an expansion cone support body coupled to the first tubular

support body. The expansion cone support body includes an N-sided tapered tubular support member, wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot. N/2 first expansion cone segments are movably coupled to the expansion cone support body, each including a first expansion cone segment body including arcuate conical outer surfaces, a first T-shaped retaining member coupled to the first expansion cone segment body for movably coupling the first expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body, and a second T-shaped retaining member coupled to the first expansion cone segment body. N/2 second expansion cone segments are also movably coupled to the expansion cone support body, each including a second expansion cone segment body including arcuate conical outer surfaces, a third T-shaped retaining member coupled to the second expansion cone segment body for movably coupling the second expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body, and a fourth T-shaped retaining member coupled to the expansion cone segment body. The first and second expansion cone segments are interleaved. The first expansion cone segment bodies are complementary shaped with respect to the second expansion cone segment bodies. A split ring collar assembly is movably coupled to the exterior of the tubular support member that includes a second tubular support body that defines N T-shaped slots for movably receiving corresponding ones of the second and fourth T-shaped retaining members of the interleaved first and second expansion cone segments, and an L-shaped retaining member coupled to the second tubular support body. A tubular actuating sleeve movably coupled to the tubular support member that includes a third tubular support body that defines a slot for receiving and mating with the L-shaped retaining member of the split ring collar.

According to another aspect of the present invention, an apparatus for radially expanding a tubular member is provided that includes a tubular support member that includes a first tubular support body defining a longitudinal passage, a first lug coupled to and extending from the first tubular support body in the radial direction, and a second lug coupled to and extending from the first tubular support body in the radial direction. An adjustable expansion cone assembly is movably coupled to the tubular support member. A first drag block assembly is movably coupled to the tubular support member that includes a first drag block body coupled to the adjustable expansion cone assembly that defines: a first J-shaped slot for receiving the first lug, and one or more first drag blocks coupled to the first drag block body. A second drag block assembly is

movably coupled to the tubular support member that includes a second drag block body that defines: a second J-shaped slot for receiving the second lug, and one or more second drag blocks coupled to the second drag block body. First and second packer cups are coupled to the tubular support member between the first and second drag block assemblies.

According to another aspect of the present invention, an apparatus for radially expanding a tubular member is provided that includes a tubular support member that includes a first tubular support body defining a longitudinal passage, a first flange coupled to the first tubular support body, a second flange coupled to the first tubular support body, a first tapered flange coupled to the first tubular support body, and a second tapered flange coupled to the first tubular support body. An adjustable expansion cone assembly is movably coupled to the tubular support member. A first collet assembly is movably coupled to the tubular support member that includes a first tubular sleeve coupled to the adjustable expansion cone assembly and defines a first counterbore for receiving the first flange, and a first radial passage, a first spring received within the first counterbore, a first retaining ring received within the first counterbore, a first load transfer pin coupled to the first retaining ring and extending through the first radial passage, a second tubular sleeve coupled to the first load transfer pin, a first resilient collet coupled to the second tubular sleeve and positioned above the first tapered flange, and a third tubular sleeve coupled to the first resilient collet. A second collet assembly is movably coupled to the tubular support member that includes a fourth tubular sleeve that defines: a second counterbore for receiving the second flange, and a second radial passage, a second spring received within the second counterbore, a second retaining ring received within the second counterbore, a second load transfer pin coupled to the second retaining ring and extending through the second radial passage, a fifth tubular sleeve coupled to the second load transfer pin, a second resilient collet coupled to the fifth tubular sleeve and positioned above the second tapered flange, and a sixth tubular sleeve coupled to the second resilient collet. First and second packer cups are coupled to the tubular support member between the first and second collet assemblies.

According to another aspect of the present invention, an apparatus for radially expanding a tubular member is provided that includes a tubular support member that includes a first tubular support body defining a longitudinal passage, a first radial passage defined in the first tubular support body fluidicly coupled to the longitudinal passage, a first flange coupled to the first tubular support body, a second flange coupled to the first tubular support body, a first tapered flange coupled to the first

tubular support body, and a second tapered flange coupled to the first tubular support body. An adjustable expansion cone assembly is movably coupled to the tubular support member. A first dog assembly is movably coupled to the tubular support member that includes a first tubular sleeve coupled to the adjustable expansion cone assembly that defines: a first counterbore for receiving the first flange, and a second radial passage, a first spring received within the first counterbore, a first retaining ring received within the first counterbore, a first load transfer pin coupled to the first retaining ring and extending through the second radial passage, a second tubular sleeve coupled to the first load transfer pin that defines: a second counterbore for receiving the first tubular sleeve, a first resilient dog coupled to the second tubular sleeve and positioned adjacent to the first tapered flange. A second dog assembly is movably coupled to the tubular support member that includes a third tubular sleeve that defines a second counterbore for receiving the second flange;

a third radial passage, and a fourth radial passage fluidicly coupled to the first radial passage, a second spring received within the second counterbore, a second retaining ring received within the second counterbore, a second load transfer pin coupled to the second retaining ring and extending through the third radial passage, a fourth tubular sleeve coupled to the second load transfer pin, a second resilient dog coupled to the fourth tubular sleeve and positioned adjacent to the second tapered flange. First and second packer cups are coupled to the tubular support member between the first and second dog assemblies.

According to another aspect of the present invention, an apparatus for radially expanding a tubular member is provided that includes a tubular support member that includes a first tubular support body defining a longitudinal passage including a throat passage, a first radial passage defined in the first tubular support body fluidicly coupled to the longitudinal passage, a first flange coupled to the first tubular support body, and a second flange coupled to the first tubular support body that defines: a second radial passage defined in the second flange fluidicly coupled to the longitudinal passage. An adjustable expansion cone assembly is movably coupled to the tubular support member. A dog assembly is movably coupled to the tubular support member that includes a first tubular sleeve coupled to the adjustable expansion cone assembly that defines a first counterbore for receiving the first flange, and a third radial passage, a spring received within the first counterbore, a retaining ring received within the first counterbore, a load transfer pin coupled to the retaining ring and extending through the third radial passage, a second tubular sleeve coupled to the first load transfer pin that defines: a first counterbore for receiving the first tubular sleeve, a second counterbore

for receiving and mating with the tapered flange, and includes a third flange that defines a third counterbore for receiving the second flange, a fourth counterbore for receiving the second flange, and a fourth radial passage, and a resilient dog coupled to the second tubular sleeve and positioned adjacent to the tapered flange. First and second packer cups are coupled to the tubular support member between the resilient dog and the third flange.

According to another aspect of the present invention, an apparatus for radially expanding a tubular member is provided that includes a tubular support member, an adjustable expansion cone assembly movably coupled to the tubular support member, and means for adjusting the adjustable expansion cone assembly.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a tubular support member. An adjustable expansion cone is movably coupled to the tubular support member that includes a plurality of expansion cone segments, and means for guiding the expansion cone segments on the tubular support member. The assembly further includes means for adjusting the adjustable expansion cone.

According to another aspect of the present invention, a method of operating an adjustable expansion cone assembly including a plurality of expansion cone segments is provided that includes guiding the expansion cone segments on a tapered body, and controllably displacing the expansion cone segments along the tapered body.

According to another aspect of the present invention, a method of operating an adjustable expansion cone assembly including a plurality of expansion cone segments is provided that includes guiding the expansion cone segments on a multi-sided tapered body, interlocking the expansion cone segments, and controllably displacing the expansion cone segments along the tapered body.

According to another aspect of the present invention, a method of operating an adjustable expansion cone assembly including a plurality of expansion cone segments is provided that includes resiliently guiding the expansion cone segments on a multi-sided tapered body, guiding each of the expansion cone segments on opposite sides in the circumferential direction, interlocking the expansion cone segments, and controllably displacing the expansion cone segments along the tapered body.

According to another aspect of the present invention, a method of operating an adjustable expansion cone assembly including a plurality of expansion cone segments is provided that includes dividing the expansion cone segments into first and second groups of expansion cone segments, interleaving the first and second groups of expansion cone segments, overlapping the first and second groups of expansion cone

segments, resiliently guiding the expansion cone segments on a multi-sided tapered body, guiding each of the expansion cone segments on opposite sides in the circumferential direction, and controllably displacing the expansion cone segments along the tapered body.

According to another aspect of the present invention, a method of operating an adjustable expansion cone assembly including a plurality of expansion cone segments is provided that includes dividing the expansion cone segments into first and second groups of expansion cone segments, interleaving the first and second groups of expansion cone segments, guiding the expansion cone segments on a multi-sided tapered body, and controllably displacing the expansion cone segments along the tapered body while also relatively displacing the first and second groups of expansion cone segments in opposite directions.

According to another aspect of the present invention, a method of plastically deforming and radially expanding an expandable tubular member using an apparatus including a tubular support member, an adjustable expansion cone assembly movably coupled to the tubular support member, and an actuator movably coupled to the tubular support member for adjusting the adjustable expansion cone assembly, is provided that includes coupling a first end of the expandable tubular member to a tubular structure, locking the actuator to the tubular support member of the apparatus, inserting the apparatus into the first end of the expandable tubular member, moving the actuator and the adjustable expansion cone assembly of the apparatus out of the second end of the expandable tubular member, reinserting the actuator of the apparatus into the second end of the expandable tubular member, unlocking the actuator from the tubular support member of the apparatus, rotating the actuator relative to the tubular support member of the apparatus, and increasing the outside diameter of the adjustable expansion cone assembly by moving the tubular support member relative to the actuator, the adjustable expansion cone assembly and the expandable tubular member, and plastically deforming and radially expanding the expandable tubular member by moving the adjustable expansion cone assembly through the expandable tubular member.

According to another aspect of the present invention, a method of plastically deforming and radially expanding an expandable tubular member using an apparatus including a tubular support member, an adjustable expansion cone assembly movably coupled to the tubular support member, and an actuator movably coupled to the tubular support member for adjusting the adjustable expansion cone assembly, is provided that includes coupling a first end of the expandable tubular member to a tubular structure, inserting the apparatus into the first end of the expandable tubular member in a first

direction, displacing the actuator of the apparatus in a second direction opposite to the first direction, applying a resilient biasing force to the adjustable expansion cone assembly in the second direction, moving the actuator and the adjustable expansion cone assembly of the apparatus out of the second end of the expandable tubular member, reinserting the actuator of the apparatus into the second end of the expandable tubular member in the second direction, increasing the outside diameter of the adjustable expansion cone assembly by displacing the actuator and the adjustable expansion cone assembly relative to the expandable tubular member in the first direction, and plastically deforming and radially expanding the expandable tubular member by moving the adjustable expansion cone assembly through the expandable tubular member in the second direction.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a plurality of expansion cone segments, means for guiding the expansion cone segments on a tapered body, and means for controllably displacing the expansion cone segments along the tapered body.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a plurality of expansion cone segments, means for guiding the expansion cone segments on a multi-sided tapered body, means for interlocking the expansion cone segments, and means for controllably displacing the expansion cone segments along the tapered body.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a plurality of expansion cone segments, means for resiliently guiding the expansion cone segments on a multi-sided tapered body, means for guiding each of the expansion cone segments on opposite sides in the circumferential direction, means for interlocking the expansion cone segments, and means for controllably displacing the expansion cone segments along the tapered body.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a plurality of expansion cone segments, means for dividing the expansion cone segments into first and second groups of expansion cone segments, means for interleaving the first and second groups of expansion cone segments, means for overlapping the first and second groups of expansion cone segments, means for resiliently guiding the expansion cone segments on a multi-sided tapered body, means for guiding each of the expansion cone segments on opposite sides in the circumferential direction, and means for controllably displacing the expansion cone segments along the tapered body.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a plurality of expansion cone segments, means for dividing the expansion cone segments into first and second groups of expansion cone segments, means for interleaving the first and second groups of expansion cone segments, means for guiding the expansion cone segments on a multi-sided tapered body, and means for controllably displacing the expansion cone segments along the tapered body while also relatively displacing the first and second groups of expansion cone segments in opposite directions.

According to another aspect of the present invention, an apparatus for plastically deforming and radially expanding an expandable tubular member is provided that includes a tubular support member, an adjustable expansion cone assembly movably coupled to the tubular support member, means for actuating the adjustable expansion cone assembly, means for locking the actuator to the tubular support member of the apparatus, means for unlocking the actuator from the tubular support member of the apparatus, and means for increasing the outside diameter of the adjustable expansion cone assembly by moving the tubular support member relative to the actuator, the adjustable expansion cone assembly, and the expandable tubular member.

According to another aspect of the present invention, an apparatus for plastically deforming and radially expanding an expandable tubular member is provided that includes a tubular support member, an adjustable expansion cone assembly movably coupled to the tubular support member, means for actuating the adjustable expansion cone assembly, means for displacing the actuator of the apparatus in a first direction, means for applying a resilient biasing force to the adjustable expansion cone assembly when the actuator is displaced in the first direction, and means for increasing the outside diameter of the adjustable expansion cone assembly by displacing the actuator and the adjustable expansion cone assembly relative to the expandable tubular member in a second direction opposite to the first direction.

Brief Description of the Drawings

Figs. 1 and 1a-1d are fragmentary cross-sectional views of an embodiment of the placement of an apparatus for radially expanding a tubular member within a tubular member within a borehole within a subterranean formation.

Fig. 1e is a cross-sectional view of an embodiment of the expansion cone support body of the apparatus of Figs. 1 and 1a-1d.

Fig. 1f is a cross-sectional view of the expansion cone support body of Fig. 1e.

Fig. 1g is a side view of an embodiment of an expansion cone segment for use in the apparatus of Figs. 1 and 1a-1d.

Fig. 1h is a front view of the expansion cone segment of Fig. 1g.

Fig. 1i is a top view of the expansion cone segment of Fig. 1g.

Fig. 1j is a top view of an embodiment of interlocking expansion cone segments for use in the apparatus of Figs. 1 and 1a-1d.

Fig. 1k is a top fragmentary circumferential view of an embodiment of the coupling arrangement between the expansion cone segments and the split ring collar for use in the apparatus of Figs. 1 and 1a-1d.

Figs. 1l and 1m are top schematic views of an embodiment of the coupling between the J-slots of the drag blocks and the lugs of the tubular support member of the apparatus of Figs. 1 and 1a-1d.

Figs. 2 and 2a-2d are fragmentary cross-sectional illustrations of the apparatus of Figs. 1 and 1a-1d during the radial expansion of the tubular member within the borehole within the subterranean formation.

Figs. 2e and 2f are illustrations of an embodiment of the J-slots of the drag blocks and the lugs of the tubular support member of the apparatus of Figs. 2 and 2a-2d.

Figs. 2g and 2h are illustrations of an alternative embodiment of the J-slots of the drag blocks and the lugs of the tubular support member of the apparatus of Figs. 2 and 2a-2d.

Figs. 3 and 3a-3c are fragmentary cross-sectional illustrations of an embodiment of the placement of an apparatus for radially expanding a tubular member within a wellbore casing within a subterranean formation.

Fig. 3d is a cross-sectional view of an embodiment of the expansion cone support body of the apparatus of Figs. 3 and 3a-3c.

Fig. 3e is a cross-sectional view of the expansion cone support body of Fig. 3d.

Fig. 3f is a side view of an embodiment of an expansion cone segment for use in the apparatus of Figs. 3 and 3a-3c.

Fig. 3g is a front view of the expansion cone segment of Fig. 3f.

Fig. 3h is a top view of the expansion cone segment of Fig. 3f.

Fig. 3i is a top view of an embodiment of interlocking expansion cone segments for use in the apparatus of Figs. 3 and 3a-3c.

Fig. 3j is a top fragmentary circumferential view of an embodiment of the coupling arrangement between the expansion cone segments and the split ring collar for use in the apparatus of Figs. 3 and 3a-3c.

Figs. 4 and 4a-4d are fragmentary cross-sectional illustrations of an embodiment of the placement of the apparatus of Figs. 3 and 3a-3c including an expandable tubular member within an expandable tubular member within a subterranean formation.

Figs. 5 and 5a-5d are fragmentary cross-sectional illustrations of an embodiment of the operation of the apparatus of Figs. 4 and 4a-4d during the radial expansion of the expandable tubular member within the borehole within the subterranean formation.

Figs. 6 and 6a-6d are fragmentary cross-sectional illustrations of an embodiment of the placement of an apparatus for radially expanding a tubular member within a borehole within a subterranean formation.

Fig. 6e is a cross-sectional view of an embodiment of the expansion cone support body of the apparatus of Figs. 6 and 6a-6d.

Fig. 6f is a cross-sectional view of the expansion cone support body of Fig. 6e.

Fig. 6g is a side view of an embodiment of an expansion cone segment for use in the apparatus of Figs. 6 and 6a-6d.

Fig. 6h is a front view of the expansion cone segment of Fig. 6g.

Fig. 6i is a top view of the expansion cone segment of Fig. 6g.

Fig. 6j is a top view of an embodiment of interlocking expansion cone segments for use in the apparatus of Figs. 6 and 6a-6d.

Fig. 6k is a top fragmentary circumferential view of an embodiment of the coupling arrangement between the expansion cone segments and the split ring collar for use in the apparatus of Figs. 6 and 6a-6d.

Figs. 7 and 7a-7c are fragmentary cross-sectional illustrations of an embodiment of the placement of the apparatus of Figs. 6 and 6a-6d including an expandable tubular member within a borehole within a subterranean formation.

Figs. 8 and 8a-8d are fragmentary cross-sectional illustrations of an embodiment of the operation of the apparatus of Figs. 7 and 7a-7d during the radial expansion of the expandable tubular member within a borehole within a subterranean formation.

Fig. 9 is a fragmentary cross sectional illustration of an embodiment of an expansion cone assembly in an unexpanded position.

Fig. 9a is a cross sectional illustration of the expansion cone assembly of Fig. 9.

Fig. 10 is a fragmentary cross sectional illustration of the expansion cone assembly of Fig. 9 in an expanded position.

Fig. 10a is a cross sectional illustration of the expansion cone assembly of Fig. 10.

Fig. 11 is a fragmentary cross sectional illustration of an embodiment of an expansion cone assembly in an unexpanded position.

Fig. 11a is a cross sectional illustration of the expansion cone assembly of Fig. 11.

Fig. 12 is a fragmentary cross sectional illustration of the expansion cone assembly of Fig. 11 in an expanded position.

Fig. 12a is a cross sectional illustration of the expansion cone assembly of Fig. 12.

Fig. 13 is a fragmentary cross sectional illustration of an embodiment of an expansion cone assembly in an unexpanded position.

Fig. 13a is a cross sectional illustration of the expansion cone assembly of Fig. 13.

Fig. 13b is a fragmentary top circumferential illustration of the expansion cone segment assembly of Fig. 13 that illustrates the interleaved sets of collets.

Fig. 13c is a fragmentary cross sectional illustration of the interleaved collets of Fig. 13b.

Fig. 14 is a fragmentary cross sectional illustration of the expansion cone assembly of Fig. 13 in an expanded position.

Fig. 14a is a cross sectional illustration of the expansion cone assembly of Fig. 14.

Figs. 15 and 15a-15c are fragmentary cross-sectional illustrations of an embodiment of the placement of an apparatus for radially expanding a tubular member within a borehole within a subterranean formation.

Fig. 15d is a cross-sectional view of an embodiment of the expansion cone support body of the apparatus of Figs. 15 and 15a-15c.

Fig. 15e is a cross-sectional view of the expansion cone support body of Fig. 15d.

Fig. 15f is a side view of an embodiment of an expansion cone segment for use in the apparatus of Figs. 15 and 15a-15c.

Fig. 15g is a front view of the expansion cone segment of Fig. 15f.

Fig. 15h is a top view of the expansion cone segment of Fig. 15f.

Fig. 15i is a top view of an embodiment of interlocking expansion cone segments for use in the apparatus of Figs. 15 and 15a-15c.

Fig. 15j is a top fragmentary circumferential view of an embodiment of the coupling arrangement between the expansion cone segments and the split ring collar for use in the apparatus of Figs. 15 and 15a-15c.

Figs. 16 and 16a-16c are fragmentary cross-sectional illustrations of an embodiment of the placement of the apparatus of Figs. 15 and 15a-15j including an expandable tubular member within a borehole within a subterranean formation.

Figs. 17 and 17a-17c are fragmentary cross-sectional illustrations of an embodiment of the operation of the apparatus of Figs. 16 and 16a-16c during the radial expansion of the expandable tubular member within a borehole within a subterranean formation.

Fig. 18a is a cross sectional illustration of an embodiment of a segmented expansion cone assembly in an unexpanded position.

Fig. 18b is a fragmentary circumferential top illustration of the expansion cone and split ring collar of Fig. 18a.

Fig. 18c is a fragmentary cross-sectional illustration of the expansion cone support flange of the expansion cone assembly of Fig. 18a.

Fig. 18d is a cross-sectional illustration of the expansion cone support flange of Fig. 18c.

Fig. 19a is a cross sectional illustration of an embodiment of the segmented expansion cone assembly of Fig. 18a in an expanded position.

Fig. 19b is a fragmentary circumferential top view of the expansion cone of Fig. 19a.

Figs. 20a-20m are top circumferential views of various alternative embodiments of interlocking expansion cone segment geometries.

Detailed Description of the Illustrative Embodiments

Referring initially to Figs. 1 and 1a-1d, an embodiment of an apparatus and method for radially expanding a tubular member will now be described. As illustrated in Figs. 1 and 1a-1d, a wellbore 100 is positioned in a subterranean formation 105. In an exemplary embodiment, the wellbore 100 may include a pre-existing cased section 110. The wellbore 100 may be positioned in any orientation from vertical to horizontal.

In order to extend the wellbore 100 into the subterranean formation 105, a drill string is used in a well known manner to drill out material from the subterranean formation 105 to form a new wellbore section 115. In a preferred embodiment, the inside diameter of the new wellbore section 115 is greater than or equal to the inside diameter of the preexisting wellbore casing 110.

A tubular member 120 defining a passage 120a may then be positioned within the wellbore section 115 with the upper end 120b of the tubular member coupled to the wellbore casing 110 and the lower end 120c of the tubular member extending into the wellbore section. The tubular member 120 may be positioned within the wellbore section 115 and coupled to the wellbore casing 110 in a conventional manner. In a preferred embodiment, the tubular member 120 is positioned within the wellbore section 115 and coupled to the wellbore casing 110 using one or more of the methods and apparatus disclosed in one or more of the following: (1) U.S. patent application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, (2) U.S. patent application serial no. 09/510,913, attorney docket no. 25791.7.02, filed on 2/23/2000, (3) U.S. patent application serial no. 09/502,350, attorney docket no. 25791.8.02, filed on 2/10/2000, (4) U.S. patent application serial no. 09/440,338, attorney docket no. 25791.9.02, filed on 11/15/1999, (5) U.S. patent application serial no. 09/523,460, attorney docket no. 25791.11.02, filed on 3/10/2000, (6) U.S. patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, (7) U.S. patent application serial no. 09/511,941, attorney docket no. 25791.16.02, filed on 2/24/2000, (8) U.S. patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, (9) U.S. patent application serial no. 09/559,122, attorney docket no. 25791.23.02, filed on 4/26/2000, (10) PCT patent application serial no. PCT/US00/18635, attorney docket no. 25791.25.02, filed on 7/9/2000, (11) U.S. provisional patent application serial no. 60/162,671, attorney docket no. 25791.27, filed on 11/1/1999, (12) U.S. provisional patent application serial no. 60/154,047, attorney docket no. 25791.29, filed on 9/16/1999, (13) U.S. provisional patent application serial no. 60/159,082, attorney docket no. 25791.34, filed on 10/12/1999, (14) U.S. provisional patent application serial no. 60/159,039, attorney docket no. 25791.36, filed on 10/12/1999, (15) U.S. provisional patent application serial no. 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999, (16) U.S. provisional patent application serial no. 60/212,359, attorney docket no. 25791.38, filed on 6/19/2000, (17) U.S. provisional patent application serial no. 60/165,228, attorney docket no. 25791.39, filed on 11/12/1999, (18) U.S. provisional patent application serial no. 60/221,443, attorney docket no. 25791.45, filed on 7/28/2000, (19) U.S. provisional patent application serial no. 60/221,645, attorney docket no. 25791.46, filed on 7/28/2000, (20) U.S. provisional patent application serial no. 60/233,638, attorney docket no. 25791.47, filed on 9/18/2000, (21) U.S. provisional patent application serial no. 60/237,334, attorney docket no. 25791.48, filed on 10/2/2000, (22) U.S. provisional patent application serial no. 60/270,007, attorney docket no. 25791.50, filed on 2/20/2001; and (23) U.S.

provisional patent application serial no. 60/262,434, attorney docket no. 25791.51, filed on 1/17/2001; and (24) U.S. provisional patent application serial no. 60/259,486, attorney docket no. 25791.52, filed on 1/3/2001, the disclosures of which are incorporated herein by reference.

As illustrated in Figs. 1 and 1a-1d, an apparatus 200 for radially expanding a tubular member may then be positioned in the new section 115 of the wellbore 100 within the tubular member 120. The apparatus 200 includes a tubular support member 205 defining an internal passage 205a that is coupled to an end of a tubular coupling 210 defining an internal passage 210a. The other end of the tubular coupling 210 is coupled to an end of a tubular support member 215 defining an internal passage 215a that includes a first lug 215b, a radial passage 215c, a first flange 215d, a second flange 215e, a second lug 215f, and an expansion cone support body 215g. The other end of the tubular support member 215 is coupled to a tubular end stop 220 that defines a passage 220a.

As illustrated in Figs. 1e and 1f, the expansion cone support body 215g includes a first end 215ga, a tapered hexagonal portion 215gb that includes a plurality of T-shaped slots 215gba provided on each of the external faceted surfaces of the tapered hexagonal portion, and a second end 215gc. In an exemplary embodiment, the angle of attack of the tapered hexagonal portion ranges from about 35 to 50 degrees for reasons to be described.

As illustrated in Figs. 1, 1a-1d, 1g, 1h, and 1i, a plurality of expansion cone segments 225 are provided that include first ends 225a that include T-shaped retaining members 225aa and second ends 225b that include T-shaped retaining members 225ba that mate with and are received within corresponding T-shaped slots 215gba on the tapered hexagonal portion 215gb of the expansion cone support body 215g, first external surfaces 225bb, second external surfaces 225bc, and third external surfaces 225bd. Thus, in an exemplary embodiment, a total of six expansion cone segments 225 are provided that are slidably coupled to corresponding sides of the tapered hexagonal portion 215gb of the expansion cone support body.

In an exemplary embodiment, the widths of the first external surfaces 225bb of the expansion cone segments 225 increase in the direction of the second external surfaces 225bc, the widths of the second external surfaces are substantially constant, and the widths of the third external surfaces 225bd decrease in the direction of the first ends 225a of the expansion cone segments for reasons to be described. In an exemplary embodiment, the first external surfaces 225bb of the expansion cone segments 225 taper upwardly in the direction of the second external surfaces 225bc,

the second external surfaces taper upwardly in the direction of the third external surfaces 225bd, and the third external surfaces 225bd taper downwardly in the direction of the first ends 225a of the expansion cone segments for reasons to be described. In an exemplary embodiment, the angle of attack of the taper of the first external surfaces 225bb of the expansion cone segments 225 are greater than the angle of attack of the taper of the second external surfaces 225bc. In an exemplary embodiment, the first and second external surfaces, 225bb and 225bc, of the expansion cone segments 225 are arcuate such that when the expansion cone segments 225 are displaced in the direction of the end stop 220, the first and second external surfaces of the expansion cone segments provide a substantially continuous outer circumferential surface for reasons to be described.

As illustrated in Fig. 1j, in an exemplary embodiment, the external surfaces, 225bb, 225bc, and 225bd, of the second ends 225b of the expansion cone segments 225 are adapted to mate with one another in order to interlock adjacent expansion cone segments.

As illustrated in Figs. 1, 1a-1d, and 1k, a split ring collar 230 that defines a passage 230a for receiving the tubular support member 215 is provided that includes a first end that includes plurality of T-shaped slots 230b for receiving and mating with corresponding T-shaped retaining members 225aa of the expansion cone segments 225 and a second end that includes an L-shaped retaining member 230c. In an exemplary embodiment, the split ring collar 230 is a conventional split ring collar commercially available from Halliburton Energy Services modified in accordance with the teachings of the present disclosure.

As illustrated in Figs. 1, 1a-1d, and 1m, a drag block assembly 235 that defines a passage 235a for receiving the tubular support member 215 is provided that includes a first end that includes an L-shaped slot 235b for receiving and mating with the L-shaped retaining member 230c of the split ring collar 230, one or more conventional drag block elements 235c, and a J-shaped slot 235d including a retaining slot 235da for receiving the second lug 215f of the tubular support member 215. In an exemplary embodiment, the longitudinal axis of the J-shaped slot 235d of the drag block assembly 235 is substantially parallel to the longitudinal axis of the tubular support member 215 for reasons to be described.

A first conventional packer cup assembly 240 that defines a passage 240a for receiving the tubular support member 215 includes a first end 240b that mates with the second flange 215e of the tubular support member, a conventional sealing cup 240c, and a second end 240d. A tubular spacer 245 that defines a passage 245a for

receiving the tubular support member 215 includes a first end 245b that mates with the second end 240c of the first packer cup assembly 240 and a second end 245c. A second conventional packer cup assembly 250 that defines a passage 250a for receiving the tubular support member 215 includes a first end 250b that mates with the second end 245c of the spacer 245, a conventional sealing cup 250c, and a second end 250d that mates with the first flange 215d of the tubular support member.

As illustrated in Figs. 1, 1a-1d, and 1l, a drag block assembly 255 that defines a passage 255a for receiving the tubular support member 215 is provided that includes a first end that includes sealing members, 255b and 255c, one or more conventional drag block elements 255d, and a J-shaped slot 255e including a retaining slot 255ea for receiving the first lug 215b of the tubular support member 215. In an exemplary embodiment, the longitudinal axis of the J-shaped slot 255e of the drag block assembly 255 is substantially parallel to the longitudinal axis of the tubular support member 215 for reasons to be described.

In an exemplary embodiment, during operation of the apparatus 200, as illustrated in Figs. 1 and 1a-1m, the apparatus may be positioned in the wellbore 115, within the tubular member 120, with the first and second lugs, 215b and 215f, respectively, positioned within the retaining slots, 255ea and 235da, respectively, of the J-slots, 255e and 235da, respectively, of the drag block assembly 255 and 235, respectively. In this manner, the drag block assembly 235 is maintained in a substantially stationary position relative to the tubular support member 215 thereby preventing the expansion cone segments 225 from being displaced downwardly in the longitudinal direction relative to the tubular support member 215 towards the end stop 220. Furthermore, in this manner, the drag block assembly 255 is also maintained in a substantially stationary position relative to the tubular support member 215 thereby preventing the drag block assembly from sealing off the radial passage 215c. In an exemplary embodiment, during the placement of the apparatus 200 within the wellbore 115 and the tubular member 120, the radial passage 215c permits fluidic materials outside of the tubular support member 215 to pass into the passage 215a thereby minimizing overpressure conditions within the annulus outside of the tubular support member.

In an exemplary embodiment, the apparatus 200 is positioned within the expandable tubular member 120 such that the expansion cone body 215g, the end stop 220, and the expansion cone segments 225 extend out of the expandable tubular member. In this manner, the expansion cone segments 225 may be driven up the tapered hexagonal portion 215gb of the expansion cone body 215g, thereby increasing

the outside diameters of the expansion cone segments, without impacting the expandable tubular member 120.

The tubular support member 215 may then be rotated relative to the drag block assemblies, 235 and 255, thereby displacing the lugs, 215f and 215b, with respect to the J-shaped slots, 235d and 255e, respectively. The tubular support member 215 may then be displaced upwardly relative to the drag block assemblies, 235 and 255, in the longitudinal direction thereby displacing the drag block assemblies downwardly relative to the tubular support member. During the longitudinal upward displacement of the tubular support member 215 relative to the drag block assemblies, 235 and 255, the drag block assemblies, 235 and 255, are maintained in a substantially stationary position with respect to the expandable tubular member 120 by the frictional forces exerted by the drag blocks, 235c and 255d, of the drag block assemblies on the expandable tubular member, and during the upward longitudinal displacement of the tubular support member 215 relative to the drag block assemblies, the lugs, 215f and 215b, are guided in a substantially longitudinal direction by the J-slots, 235d and 255e, respectively, of the drag block assemblies.

The downward longitudinal displacement of the drag block assembly 235 relative to the tubular support member 215 displaces the split ring collar 230 downwardly along with the expansion cone segments 225. As a result, the expansion cone segments 225 are driven up the tapered hexagonal portion 215gb of the expansion cone support body 215g until the end faces of the expansion cone segments impact the stop member 220. As a result, the outside diameter of the expansion cone segments 225 increases. In an exemplary embodiment, once the expansion cone segments 225 impact the stop member 220, the outer surfaces, 225bb and 225bc, of the expansion cone segments provide a substantially continuous outer surface in the circumferential direction having a diameter that is greater than the inside diameter of the expandable tubular member 120. The downward longitudinal displacement of the drag block assembly 255 relative to the tubular support member 215 seals off the radial passage 215c thereby preventing the pressurized fluidic material 275 from entering the annulus surrounding the tubular support member 215 through the radial passage.

In an exemplary embodiment, as illustrated in Figs. 2 and 2a-2f, the expandable tubular member 120 may then be radially expanded using the apparatus 200 by injecting a fluidic material 275 into the apparatus through the passages 205a, 210a, and 215a. The injection of the fluidic material 275 may pressurize the interior 120a of the expandable tubular member 120. In addition, because the packer cup assemblies, 240 and 250, seal off an annular region 120aa below the packer cup assemblies .

between the expandable tubular member 120 and the tubular support member 215, the injection of the fluidic material 275 may also pressurize the annular region.

The continued injection of the fluidic material 275 may then pressurize the interior 120a of the expandable tubular member 120 thereby plastically deforming and radially expanding the expandable tubular member off of the expansion cone segments 225. Because the outer surfaces, 225bb and 225bc, of the expansion cone segments 225 are tapered, the plastic deformation and radial expansion of the expandable tubular member 120 proximate the expansion cone segments is facilitated. Furthermore, in an exemplary embodiment, the continued injection of the fluidic material 275 also pressurizes the annular region 120aa defined between the interior surface of the expandable tubular member 120 and the exterior surface of the tubular support member 215 that is bounded on the upper end by the packer cup assembly 240 and on the lower end by the expansion cone segments 225. Furthermore, in an exemplary embodiment, the pressurization of the annular region 120aa also radially expands the surrounding portion of the expandable tubular member 120. In this manner, the plastic deformation and radial expansion of the expandable tubular member 120 is enhanced. Furthermore, during operation of the apparatus 200, the packer cup assemblies 240 and 250 prevent the pressurized fluidic material 275 from passing above and beyond the packer cup assemblies and thereby define the length of the pressurized annular region 120aa. In an exemplary embodiment, the pressurization of the annular region 120aa decreases the operating pressures required for plastic deformation and radial expansion of the expandable tubular member 120 by as much as 50% and also reduces the angle of attack of the tapered external surfaces, 225bb and 225bc, of the expansion cone segments 225.

The radial expansion of the expandable tubular member 120 may then continue until the upper end 120b of the expandable tubular member is radially expanded and plastically deformed along with the overlapping portion of the wellbore casing 110. Because the expansion cone segments 225 may be adjustable positioned from an outside diameter less than the inside diameter of the expandable tubular member 120 to an outside diameter substantially equal to the inside diameter of the pre-existing casing 110, the resulting wellbore casing, including the casing 110 and the radially expanded tubular member 120, created by the operation of the apparatus 200 may have a single substantially constant inside diameter thereby providing a mono-diameter wellbore casing.

If the expansion cone segments 225 become lodged within the tubular member 120 during the radial expansion process, the tubular support member 215 may be

displaced downwardly in the longitudinal direction and then rotated relative to the drag block assemblies, 235 and 255, thereby positioning the lugs, 215b and 215f, within the retaining slots, 255ea and 235da, respectively, of the J-slots, 255e and 235d, respectively. As a result, the expansion cone segments 225 may be displaced down the tapered hexagonal portion 215gb of the expansion cone support body 215g and away from the end stop 220 thereby decreasing the external diameter of the expansion cone segments. In this manner, the tubular support member 205, the tubular support member 210, the tubular support member 215, the end stop 220, the expansion cone segments 225, the split ring collar 230, the drag block assembly 235, the pack cup assembly 240, the spacer 245, the packer cup assembly 250, and the drag block assembly 255 may then be removed from the tubular member 120.

During the radial expansion process, the expansion cone segments 225 may be raised out of the expanded portion of the tubular member 120 by applying an upward axial force to the tubular support member 215. In a preferred embodiment, during the radial expansion process, the expansion cone segments 225 are raised at approximately the same rate as the tubular member 120 is expanded in order to keep the tubular member stationary relative to the new wellbore section 115. In an alternative preferred embodiment, the expansion cone segments 225 are maintained in a stationary position during the radial expansion process thereby allowing the tubular member 120 to be radially expanded and plastically deformed off of the expansion cone segments 225 and into the new wellbore section 115 under the force of gravity and the operating pressure of the interior of the tubular member 120.

In a preferred embodiment, when the upper end portion of the expandable tubular member 120 and the lower portion of the wellbore casing 110 that overlap with one another are plastically deformed and radially expanded by the expansion cone segments 225, the expansion cone segments 225 are displaced out of the wellbore 100 by both the operating pressure within the interior of the tubular member 120 and a upwardly directed axial force applied to the tubular support member 205.

In a preferred embodiment, the operating pressure and flow rate of the fluidic material 275 is controllably ramped down when the expansion cone segments 225 reach the upper end portion of the expandable tubular member 120. In this manner, the sudden release of pressure caused by the complete radial expansion and plastic deformation of the expandable tubular member 120 off of the expansion cone segments 225 can be minimized. In a preferred embodiment, the operating pressure is reduced in a substantially linear fashion from 100% to about 10% during the end of the

extrusion process beginning when the expansion cone segments 225 are within about 5 feet from completion of the extrusion process.

Alternatively, or in combination, the wall thickness of the upper end portion of the expandable tubular member 120 is tapered in order to gradually reduce the required operating pressure for plastically deforming and radially expanding the upper end portion of the tubular member. In this manner, shock loading of the apparatus is at least reduced.

Alternatively, or in combination, a shock absorber is provided in the tubular support member 205 in order to absorb the shock caused by the sudden release of pressure. The shock absorber may comprise, for example, any conventional commercially available shock absorber, bumper sub, or jars adapted for use in wellbore operations.

Alternatively, or in combination, an expansion cone catching structure is provided in the upper end portion of the expandable tubular member 120 in order to catch or at least decelerate the expansion cone segments 225.

Alternatively, or in combination, during the radial expansion process, an upward axial force is applied to the tubular support member 215 sufficient to plastically deform and radially expand the tubular member 120 off of the external surfaces, 225bb and 225bc, of the expansion cone segments 225.

Alternatively, or in combination, in order to facilitate the pressurization of the interior 120a of the expandable tubular member by the injection of the fluidic materials 275, the region within the wellbore section 115 below the apparatus 200 may be fluidicly sealed off in a convention manner using, for example, a packer.

Once the radial expansion process is completed, the tubular support member 205, the tubular support member 210, the tubular support member 215, the end stop 220, the expansion cone segments 225, the split ring collar 230, the drag block assembly 235, the pack cup assembly 240, the spacer 245, the packer cup assembly 250, and the drag block assembly 255 are removed from the wellbore 100.

In an alternative embodiment, as illustrated in Figs. 2h and 2i, the J-slots, 235d and 255e, include one or more intermediate retaining slots, 235db and 255eb, respectively, that permit the relative longitudinal displacement of the tubular support member 215 relative to the drag block assemblies, 235 and 255, to be set at one or more intermediate stop positions. In this manner, the expansion segments 225 may be positioned at one or more intermediate positions on the tapered hexagonal portion 215gb of the expansion cone support body 215g thereby permitting the external diameter of the expansion cone segments 225 to be adjusted to one or more

intermediate sizes. In this manner, the radial expansion and plastic deformation of the expandable tubular member 120 be provided in different operation stages, each having a different expansion diameter. Furthermore, if the expansion cone segments 225 become lodged within the expandable tubular member 120, then the position of the expansion cone segments may be adjusted to provide a smaller outside diameter and the radial expansion process may be continued by injecting the fluidic material 275 and/or applying an upward axial force to the tubular support member 215.

Referring to Figs. 3 and 3a-3j, an alternative embodiment of an apparatus 300 for forming a wellbore casing in a subterranean formation will now be described. The apparatus 300 includes a tubular support member 305 defining an internal passage 305a that is coupled to an end of a tubular coupling 310 defining an internal passage 310a. The other end of the tubular coupling 310 is coupled to an end of a tubular support member 315 defining an internal passage 315a that includes a first flange 315b having oppositely tapered end-walls, 315ba and 315bb, a second flange 315c, a radial passage 315d, a third flange 315e, a fourth flange 315f, a fifth flange 315g having oppositely tapered end-walls, 315ga and 315gb, a fifth flange 315h, and an expansion cone support body 315i. The other end of the tubular support member 315 is coupled to a tubular end stop 320 that defines a passage 320a.

As illustrated in Figs. 3d and 3e, the expansion cone support body 315i includes a first end 315ia, a tapered hexagonal portion 315ib that includes a plurality of T-shaped slots 315iba provided on each of the external faceted surfaces of the tapered hexagonal portion, and a second end 315ic. In an exemplary embodiment, the angle of attack of the tapered hexagonal portion 315ib ranges from about 35 to 50 degrees for reasons to be described.

As illustrated in Figs. 3, 3a-3c, and 3f-3h, a plurality of expansion cone segments 325 are provided that include first ends 325a that include T-shaped retaining members 325aa and second ends 325b that include T-shaped retaining members 325ba that mate with and are received within corresponding T-shaped slots 315iba on the tapered hexagonal portion 315ib of the expansion cone support body 315i, first external surfaces 325bb, second external surfaces 325bc, and third external surfaces 325bd. Thus, in an exemplary embodiment, a total of six expansion cone segments 325 are provided that are slidably coupled to corresponding sides of the tapered hexagonal portion 315ib of the expansion cone support body 315i.

In an exemplary embodiment, the widths of the first external surfaces 325bb of the expansion cone segments 325 increase in the direction of the second external surfaces 325bc, the widths of the second external surfaces are substantially constant,

and the widths of the third external surfaces 325bd decrease in the direction of the first ends 325a of the expansion cone segments for reasons to be described. In an exemplary embodiment, the first external surfaces 325bb of the expansion cone segments 325 taper upwardly in the direction of the second external surfaces 325bc, the second external surfaces taper upwardly in the direction of the third external surfaces 325bd, and the third external surfaces 325bd taper downwardly in the direction of the first ends 325a of the expansion cone segments for reasons to be described. In an exemplary embodiment, the angle of attack of the taper of the first external surfaces 325bb of the expansion cone segments 325 are greater than the angle of attack of the taper of the second external surfaces 325bc. In an exemplary embodiment, the first and second external surfaces, 325bb and 325bc, of the expansion cone segments 325 are arcuate such that when the expansion cone segments 325 are displaced in the direction of the end stop 320, the first and second external surfaces of the expansion cone segments provide a substantially continuous outer circumferential surface for reasons to be described.

As illustrated in Fig. 3i, in an exemplary embodiment, the external surfaces, 325bb, 325bc, and 325bd, of the second ends 325b of the expansion cone segments 325 are adapted to mate with one another in order to interlock adjacent expansion cone segments.

A split ring collar 330 that defines a passage 330a for receiving the tubular support member 315 is provided that includes a first end that includes plurality of T-shaped slots 330b for receiving and mating with corresponding T-shaped retaining members 325aa of the expansion cone segments 325 and a second end that includes an L-shaped retaining member 330c. In an exemplary embodiment, the split ring collar 330 is a conventional split ring collar commercially available from Halliburton Energy Services modified in accordance with the teachings of the present disclosure.

A collet assembly 335 is provided that includes a support ring 335a that defines a passage 335aa for receiving the tubular support member 315 and is coupled to an end of a resilient collet 335b having upper and lower sets of oppositely tapered shoulders, 335ba and 335bb, and, 335bc and 335bd, respectively, that is positioned proximate the fourth flange 315g of the tubular support member 315. The other end of the collet 335b is coupled to an end of a tubular sleeve 335c that defines a passage 335ca. The other end of the tubular sleeve 335c is coupled to an end of a pin 335d. The other end of the pin 335d is coupled to a ring 335e that defines a passage 335ea for receiving the fifth flange 315h of the tubular support member 315. An end of a tubular coupling sleeve 335f that defines a passage 335fa for receiving the tubular

support member 315 is received within the opening 335ca of the tubular sleeve 335c that includes a recess 335fb for receiving the fifth flange 315h of the tubular support member 315 and the ring 335e, and a radial passage 335fc for receiving the pin 335d. Another end of the tubular coupling sleeve 335f includes a passage 335fd for receiving the tubular support member 315 and a slot 335fe for receiving the L-shaped retaining member 330c of the split ring collar 330. A ring 335g that defines a passage 335ga for receiving the tubular support member 315, a spring 335h, and a ring 335i that defines a passage 335ia for receiving the tubular support member 315 are also received within the recess 335fb. The ring 335g is positioned proximate one end of the recess 335fb, the ring 335i is positioned proximate the fifth flange 315h of the tubular support member 315 within the other end of the recess, and the spring 335h is positioned between the rings.

A first conventional packer cup assembly 340 that defines a passage 340a for receiving the tubular support member 315 includes a first end 340b that mates with the fourth flange 315f of the tubular support member, a conventional sealing cup 340c, and a second end 340d. A tubular spacer 345 that defines a passage 345a for receiving the tubular support member 315 includes a first end 345b that mates with the second end 340d of the first packer cup assembly 340 and a second end 345c. A second conventional packer cup assembly 350 that defines a passage 350a for receiving the tubular support member 315 includes a first end 350b that mates with the second end 345c of the spacer 345, a conventional sealing cup 350c, and a second end 350d that mates with the third flange 315e of the tubular support member.

A collet assembly 355 is provided that includes a support ring 355a that defines a passage 355aa for receiving the tubular support member 315 and is coupled to an end of a resilient collet 355b having upper and lower sets of oppositely tapered shoulders, 355ba and 355bb, and, 355bc and 355bd, respectively, that is positioned proximate the first flange 315b of the tubular support member 315. The other end of the collet 355b is coupled to an end of a tubular sleeve 355c that defines a passage 355ca. The other end of the tubular sleeve 355c is coupled to an end of a pin 355d. The other end of the pin 355d is coupled to a ring 355e that defines a passage 355ea for receiving the second flange 315c of the tubular support member 315. An end of a tubular sleeve 355f that defines a passage 355fa for receiving the tubular support member 315 is received within the opening 355ca of the tubular sleeve 355c that includes a recess 355fb for receiving the second flange 315c of the tubular support member 315 and the ring 355e, and a radial passage 355fc for receiving the pin 355d. Another end of the tubular sleeve 355f includes a passage 355fd for receiving the tubular support member

315, a recess 355fe for receiving an end of the tubular sleeve 355c, and sealing members 355ff. A ring 355g that defines a passage 355ga for receiving the tubular support member 315 and a spring 355h are also received within the recess 355fb. An end of the ring 355g is positioned proximate the second flange 315c of the tubular support member 315 within an end of the recess 355fb and the other end of the ring is positioned an end of the spring 355h. The other end of the spring 355h is positioned proximate the other end of the recess 355fb.

In an exemplary embodiment, during operation of the apparatus 300, as illustrated in Figs. 3 and 3a-3j, the apparatus may be initially positioned in the wellbore 100, within the casing 110, with the collet assemblies 335 and 355 positioned in a neutral position in which the radial passage 315d of the tubular support member 315 is not covered by the tubular sleeve 355f and the expansion cone segments 325 are not driven up the tapered hexagonal portion 315ib of the expansion cone support body 315i of the tubular support member 315 into contact with the stop member 320. In this manner, fluidic materials within the interior 315a of the tubular support member 315 may pass through the radial passage 315d into the annulus between the apparatus 300 and the casing 110 thereby preventing over pressurization of the annulus. Furthermore, in this manner, the outside diameter of the expansion cone segments 325 is less than or equal to the outside diameter of the stop member 320 thereby permitting the apparatus 300 to be displaced within the casing 110.

As illustrated in Figs. 4, and 4a-4d, the apparatus 300 may then be positioned in the tubular member 120. During the insertion of the apparatus into the tubular member 120, the upper end 120b of the tubular member may impact the tapered shoulders, 335bb and 355bb, of the collets, 335b and 355b, respectively, thereby driving the collets backward until the tapered shoulders, 335bd and 355bd, of the collets are positioned proximate the tapered shoulders, 315ga and 315ba, respectively, of the tubular support member. As a result, the support rings, 335a and 355a, the collets, 335b and 355b, the tubular sleeves, 335c and 355c, the pins, 335d and 355d, the rings, 335e and 355e, and the rings, 335g and 355g, of the collet assemblies, 335 and 355, respectively, are driven backward, compressing the springs, 335h and 355h, thereby applying axial biasing forces to the tubular coupling sleeve 335f and the tubular sleeve 355f, respectively. In this manner, an axial biasing force is applied to the split ring collar 330 and the expansion cone segments 325 that prevents the expansion cone segments from being driven up the tapered hexagonal portion 315ib of the expansion cone support body 315i of the tubular support member 315 into contact with the stop member 320. Thus, the outside diameter of the expansion cone segments

325 is maintained in a position that is less than the inside diameter of the tubular member 120 thereby permitting the apparatus 300 to be displaced within the tubular member. Furthermore, in this manner, an axial biasing force is applied to the tubular sleeve 355f thereby preventing the tubular sleeve from covering the radial passage 315d in the tubular support member 315. Thus, fluidic materials within the interior 315a of the tubular support member 315 may pass through the radial passage 315d into the annulus between the apparatus 300 and the tubular member 120 thereby preventing over pressurization of the annulus.

The apparatus 300 may then be at least partially positioned in the open hole section 115a of the wellbore section 115, beyond the lower end 120c of the tubular member 120. In an exemplary embodiment, that portion of the apparatus 300 that includes the stop member 320, the expansion cone segments 325, the split ring collar 330, the collet assembly 335, the packer cup assembly 340, the spacer 345, the packer cup assembly 350, and the collet assembly 355 is then positioned in the open hole section 115a of the wellbore section 115, beyond the lower end 120 of the tubular member for reasons to be described. Because the collets, 335b and 355b, are resilient, once the apparatus 300 has been positioned in the open hole section 115a of the wellbore section 115, beyond the lower end 120c of the tubular member 120, the tapered shoulders, 335ba and 355ba, of the collets may spring outwardly in the radial direction.

The apparatus 300 may then be repositioned at least partially back within the tubular member 120. During the re-insertion of the apparatus into the tubular member 120, the lower end 120c of the tubular member may impact the tapered shoulders, 335ba and 355ba, of the collets, 335b and 355b, respectively, thereby driving the collets forward until the tapered shoulders, 335bc and 355bc, of the collets are positioned proximate the tapered shoulders, 315gb and 315bb, respectively, of the tubular support member 315. As a result, the support rings, 335a and 355a, the collets, 335b and 355b, the tubular sleeves, 335c and 355c, the pins, 335d and 355d, the rings, 335e and 355e, the tubular coupling sleeve 335f, the tubular sleeve 355f, the rings, 335g and 355g, and the ring 335i of the collet assemblies, 335 and 355, respectively, are driven forward, thereby compressing the springs, 335h and 355h, thereby sealing off the radial passage 315d and driving the expansion cone segments 325 up the tapered hexagonal portion 315ib of the expansion cone support body 315i of the tubular support member 315 into contact with the stop member 320.

As a result, the outside diameter of the expansion cone segments 325 is now greater than the inside diameter of expandable tubular member 120 thereby permitting

the apparatus 300 to be used to radially expand and plastically deform the tubular member, and fluidic materials within the interior 315a of the tubular support member 315 may no longer pass through the radial passage 315d into the annulus between the apparatus 300 and the tubular member thereby permitting the interior of the apparatus to be pressurized.

The apparatus 300 may then be operated to radially expand and plastically deform the tubular member 120 by applying an upward axial force to the tubular support member 315 and/or by injecting a pressurized fluidic material into the tubular support member.

In particular, as illustrated in Figs. 5 and 5a-5d, the expandable tubular member 120 may then be radially expanded using the apparatus 300 by injecting a fluidic material 275 into the apparatus through the passages 305a, 310a, 315a, and 320a. The injection of the fluidic material 275 may pressurize the interior 120a of the expandable tubular member 120. In addition, because the packer cup assemblies, 340 and 350, seal off an annular region 120aa below the packer cup assemblies between the expandable tubular member 120 and the tubular support member 315, the injection of the fluidic material 275 may also pressurize the annular region.

The continued injection of the fluidic material 275 may then pressurize the interior 120a of the expandable tubular member 120 thereby plastically deforming and radially expanding the expandable tubular member off of the expansion cone segments 325. Because the outer surfaces, 325bb and 325bc, of the expansion cone segments 325 are tapered, the plastic deformation and radial expansion of the expandable tubular member 120 proximate the expansion cone segments is facilitated. Furthermore, in an exemplary embodiment, the continued injection of the fluidic material 275 also pressurizes the annular region 120aa defined between the interior surface of the expandable tubular member 120 and the exterior surface of the tubular support member 315 that is bounded on the upper end by the packer cup assembly 340 and on the lower end by the expansion cone segments 325. Furthermore, in an exemplary embodiment, the pressurization of the annular region 120aa also radially expands at least a portion of the surrounding portion of the expandable tubular member 120. In this manner, the plastic deformation and radial expansion of the expandable tubular member 120 is enhanced. Furthermore, during operation of the apparatus 300, the packer cup assemblies 340 and 350 prevent the pressurized fluidic material 275 from passing above and beyond the packer cup assemblies and thereby define the length of the pressurized annular region 120aa. In an exemplary embodiment, the pressurization of the annular region 120aa decreases the operating pressures required

for plastic deformation and radial expansion of the expandable tubular member 120 by as much as 50% and also reduces the angle of attack of the tapered external surfaces, 325bb and 325bc, of the expansion cone segments 325.

The radial expansion of the expandable tubular member 120 may then continue until the upper end 120b of the expandable tubular member is radially expanded and plastically deformed along with the overlapping portion of the wellbore casing 110. Because the expansion cone segments 325 may be adjustable positioned from an outside diameter less than the inside diameter of the expandable tubular member 120 to an outside diameter substantially equal to the inside diameter of the pre-existing casing 110, the resulting wellbore casing, including the casing 110 and the radially expanded tubular member 120, created by the operation of the apparatus 300 may have a single substantially constant inside diameter thereby providing a mono-diameter wellbore casing.

During the radial expansion process, the expansion cone segments 325 may be raised out of the expanded portion of the tubular member 120 by applying an upward axial force to the tubular support member 315. In a preferred embodiment, during the radial expansion process, the expansion cone segments 325 are raised at approximately the same rate as the tubular member 120 is expanded in order to keep the tubular member stationary relative to the new wellbore section 115.

In a preferred embodiment, when the upper end portion of the expandable tubular member 120 and the lower portion of the wellbore casing 110 that overlap with one another are plastically deformed and radially expanded by the expansion cone segments 325, the expansion cone segments are displaced out of the wellbore 100 by both the operating pressure within the interior of the tubular member 120 and a upwardly directed axial force applied to the tubular support member 305.

In a preferred embodiment, the operating pressure and flow rate of the fluidic material 275 is controllably ramped down when the expansion cone segments 325 reach the upper end portion of the expandable tubular member 120. In this manner, the sudden release of pressure caused by the complete radial expansion and plastic deformation of the expandable tubular member 120 off of the expansion cone segments 325 can be minimized. In a preferred embodiment, the operating pressure is reduced in a substantially linear fashion from 100% to about 10% during the end of the extrusion process beginning when the expansion cone segments 325 are within about 5 feet from completion of the extrusion process.

Alternatively, or in combination, the wall thickness of the upper end portion of the expandable tubular member 120 is tapered in order to gradually reduce the

required operating pressure for plastically deforming and radially expanding the upper end portion of the tubular member. In this manner, shock loading of the apparatus is at least reduced.

Alternatively, or in combination, a shock absorber is provided in the tubular support member 305 in order to absorb the shock caused by the sudden release of pressure. The shock absorber may comprise, for example, any conventional commercially available shock absorber, bumper sub, or jars adapted for use in wellbore operations.

Alternatively, or in combination, an expansion cone catching structure is provided in the upper end portion of the expandable tubular member 120 in order to catch or at least decelerate the expansion cone segments 325.

Alternatively, or in combination, during the radial expansion process, an upward axial force is applied to the tubular support member 315 sufficient to plastically deform and radially expand the tubular member 120 off of the external surfaces, 225bb and 225bc, of the expansion cone segments 325.

Alternatively, or in combination, in order to facilitate the pressurization of the interior 120a of the expandable tubular member by the injection of the fluidic materials 275, the region within the wellbore section 115 below the apparatus 300 may be fluidicly sealed off in a convention manner using, for example, a packer.

Once the radial expansion process is completed, the tubular support member 305, the tubular support member 310, the tubular support member 315, the end stop 320, the expansion cone segments 325, the split ring collar 330, the collet assembly 335, the packer cup assembly 340, the spacer 345, the packer cup assembly 350, and the collet assembly 355 are removed from the wellbores 100 and 115.

Referring to Figs. 6 and 6a-6k, an alternative embodiment of an apparatus 400 for forming a wellbore casing in a subterranean formation will now be described. The apparatus 400 includes a tubular support member 405 defining an internal passage 405a that is coupled to an end of a tubular coupling 410 defining an internal passage 410a. The other end of the tubular coupling 410 is coupled to an end of a tubular support member 415 defining an internal passage 415a that includes a first flange 415b, a first radial passage 415c, a second radial passage 415d, a second flange 415e, a stepped flange 415f, a third flange 415g, a fourth flange 415h, a fifth flange 415i, and an expansion cone body 415j. The other end of the tubular support member 415 is coupled to a tubular end stop 420 that defines a passage 420a.

As illustrated in Figs. 6e and 6f, the expansion cone support body 415j includes a first end 415ja, a tapered hexagonal portion 415jb that includes a plurality of T-

shaped slots 415jba provided on each of the external faceted surfaces of the tapered hexagonal portion, and a second end 415jc. In an exemplary embodiment, the angle of attack of the tapered hexagonal portion 415jb ranges from about 35 to 50 degrees for reasons to be described.

As illustrated in Figs. 6, 6a-6d, and 6g-6i, a plurality of expansion cone segments 425 are provided that include first ends 425a that include T-shaped retaining members 425aa and second ends 425b that include T-shaped retaining members 425ba that mate with and are received within corresponding T-shaped slots 415jba on the tapered hexagonal portion 415jb of the expansion cone support body 415j, first external surfaces 425bb, second external surfaces 425bc, and third external surfaces 425bd. Thus, in an exemplary embodiment, a total of six expansion cone segments 425 are provided that are slidably coupled to corresponding sides of the tapered hexagonal portion 415jb of the expansion cone support body 415j.

In an exemplary embodiment, the widths of the first external surfaces 425bb of the expansion cone segments 425 increase in the direction of the second external surfaces 425bc, the widths of the second external surfaces are substantially constant, and the widths of the third external surfaces 425bd decrease in the direction of the first ends 425a of the expansion cone segments for reasons to be described. In an exemplary embodiment, the first external surfaces 425bb of the expansion cone segments 425 taper upwardly in the direction of the second external surfaces 425bc, the second external surfaces taper upwardly in the direction of the third external surfaces 425bd, and the third external surfaces 425bd taper downwardly in the direction of the first ends 425a of the expansion cone segments for reasons to be described. In an exemplary embodiment, the angle of attack of the taper of the first external surfaces 425bb of the expansion cone segments 425 are greater than the angle of attack of the taper of the second external surfaces 425bc. In an exemplary embodiment, the first and second external surfaces, 425bb and 425bc, of the expansion cone segments 425 are arcuate such that when the expansion cone segments 425 are displaced in the direction of the end stop 420, the first and second external surfaces of the expansion cone segments provide a substantially continuous outer circumferential surface for reasons to be described.

As illustrated in Fig. 6j, in an exemplary embodiment, the external surfaces, 425bb, 425bc, and 425bd, of the second ends 425b of the expansion cone segments 425 are adapted to mate with one another in order to interlock adjacent expansion cone segments.

A split ring collar 430 that defines a passage 430a for receiving the tubular support member 415 is provided that includes a first end that includes plurality of T-shaped slots 430b for receiving and mating with corresponding T-shaped retaining members 425aa of the expansion cone segments 425 and a second end that includes an L-shaped retaining member 430c. In an exemplary embodiment, the split ring collar 430 is a conventional split ring collar commercially available from Halliburton Energy Services modified in accordance with the teachings of the present disclosure.

A dog assembly 435 is provided that includes a tubular sleeve 435a that defines a passage 435aa for receiving the tubular support member 415 that includes a first end that includes a slot 435ab for receiving and mating with the L-shaped retaining member 430c of the split ring collar 430, a radial passage 435ac, and a recess 435ad for receiving the fifth flange 415a of the tubular support member 415. A second end of the tubular sleeve 435a includes a flange 435ae that mates with the fourth flange 415h of the tubular support member 415. A retaining ring 435b that defines a passage 435ba for receiving the fifth flange 415i is received within the recess 435ad of the tubular sleeve 435a and is coupled to an end of a load transfer pin 435c. The opposite end of the load transfer pin 435c is received within the radial passage 435ac of the tubular sleeve 435a and is coupled to an end of a tubular sleeve 435d that includes a recess 435da at a first end for receiving the tubular sleeve 435a, and a radial opening 435dc for receiving a conventional resilient dog 435e. A spring 435f and a ring 435g that defines a passage 435ga for receiving the tubular support member 415 are received within the recess 435ad cf the tubular sleeve 435a between a first end of the recess and the fifth flange 415i of the tubular support member.

A first conventional packer cup assembly 440 that defines a passage 440a for receiving the tubular support member 415 includes a first end 440b that mates with the fourth flange 415g of the tubular support member, a conventional sealing cup 440c, and a second end 440d. A tubular spacer 445 that defines a passage 445a for receiving the tubular support member 415 includes a first end 445b that mates with the second end 440d of the first packer cup assembly 440 and a second end 445c. A second conventional packer cup assembly 450 that defines a passage 450a for receiving the tubular support member 415 includes a first end 450b that mates with the second end 445c of the spacer 445, a conventional sealing cup 450c, and a second end 450d that mates with the stepped flange 415f of the tubular support member.

A dog assembly 455 is provided that includes a tubular sleeve 455a that defines a passage 455aa for receiving the tubular support member 415. A first end of the tubular sleeve 455a includes a radial opening 455ab for receiving a conventional

resilient dog 455b. A second end of the tubular sleeve 455a includes a recess 455ac and is coupled to an end of a load transfer pin 455c. The opposite end of the load transfer pin 455c is coupled to a retaining ring 455d that defines a passage 455da for receiving the tubular support member 415. A tubular sleeve 455e is received within the recess 455ac of the tubular sleeve 455a that defines a passage 455ea for receiving the tubular support member 415 and includes a first end that includes a radial passage 455eb for receiving the load transfer pin 455c and a recess 455ec for receiving a spring 455f. A ring 455g that defines a passage 455ga for receiving the tubular support member 415 is further received within the recess 455ec of the tubular sleeve 455e between the spring 455f and the second flange 415e of the tubular support member 415. A second end of the tubular sleeve 455e includes a radial passage 455ed, sealing members, 455ef and 455eg, and a recess 455eh that mates with the first flange 415b of the tubular support member 415.

In an exemplary embodiment, during operation of the apparatus 400, as illustrated in Figs. 6 and 6a-6k, the apparatus may be initially positioned in the wellbore 100, within the casing 110, with the dog assemblies 435 and 455 positioned in a neutral position in which the radial passage 415d of the tubular support member 415 is fluidicly coupled to the radial passage 455ed of the dog assembly 455 and the expansion cone segments 425 are not driven up the tapered hexagonal portion 415jb of the expansion cone support body 415j of the tubular support member 415 into contact with the stop member 320. In this manner, fluidic materials within the interior 415a of the tubular support member 415 may pass through the radial passages, 415d and 455ed, into the annulus between the apparatus 400 and the casing 110 thereby preventing over pressurization of the annulus. Furthermore, in this manner, the outside diameter of the expansion cone segments 425 is less than or equal to the outside diameter of the stop member 420 thereby permitting the apparatus 400 to be displaced within the casing 110.

As illustrated in Figs. 7, and 7a-7c, the apparatus 400 may then be positioned in the tubular member 120. During the insertion of the apparatus into the tubular member 120, the upper end 120b of the tubular member may impact the ends of the resilient dogs, 435e and 455b, of the dog assemblies, 435 and 455, respectively, thereby driving the resilient dogs, 435e and 455b, backwards off of and adjacent to one side of the flanges, 415h and 415f, respectively. As a result of the backward axial displacement of the resilient dog 435e, the tubular sleeve 435d, the pin 435c, the retaining ring 435b, and the ring 435g of the dog assembly 435 are driven backward thereby compressing the spring 435f and applying an axial biasing force to the tubular

sleeve 435a that prevents the expansion cone segments 425 from being displaced toward the end stop 420. As a result of the backward axial displacement of the resilient dog 455b, the tubular sleeve 455a, the pin 455c, the retaining ring 455d, and the ring 455g of the dog assembly 455 are driven backward thereby compressing the spring 455f and applying an axial biasing force to the tubular sleeve 455e that prevents the radial passages, 415d and 455ed from being fluidicly decoupled.

The apparatus 400 may then be at least partially positioned in the open hole section 115a of the wellbore section 115, beyond the lower end 120c of the tubular member 120. In an exemplary embodiment, that portion of the apparatus 400 that includes the stop member 420, the expansion cone segments 425, the split ring collar 430, the dog assembly 435, the packer cup assembly 440, the spacer 445, the packer cup assembly 450, and the dog assembly 455 is then positioned in the open hole section 115a of the wellbore section 115, beyond the lower end 120 of the tubular member for reasons to be described. Because the dogs, 435e and 455b, of the dog assemblies, 435 and 455, respectively, are resilient, once the apparatus 400 has been positioned in the open hole section 115a of the wellbore section 115, beyond the lower end 120c of the tubular member 120, the resilient dogs, 435e and 455b, of the dog assemblies may spring outwardly in the radial direction.

The apparatus 400 may then be repositioned at least partially back within the tubular member 120. During the re-insertion of the apparatus into the tubular member 120, the lower end 120c of the tubular member may impact the ends of the resilient dogs, 435e and 455b, of the dog assemblies, 435 and 455, respectively, thereby driving the resilient dogs forward until the resilient dogs are positioned beyond and adjacent to the other side of the flanges, 415h and 415f, of the tubular support member 415.

As a result, of the forward axial displacement of the resilient dog 435e, the tubular sleeve 435a, the retaining ring 435b, the pin 435c, the tubular sleeve 435d, the spring 435f, and the ring 435g of the dog assembly 435 are displaced in the forward axial direction thereby also displacing the split ring collar 430 and the expansion cone segments 425 in the forward axial direction. As a result, the expansion cone segments 425 are driven up the tapered hexagonal portion 415jb of the expansion cone support body 415j of the tubular support member 415 into contact with the stop member 320.

As a result of the forward axial displacement of the resilient dog 455b, the tubular sleeve 455a, the pin 455c, the retaining ring 455d, the tubular sleeve 455e. the spring 455f, and the ring 455g of the dog assembly 455 are driven forward in the axial direction thereby fluidicly decoupling the radial passages, 415d and 455ed, and fluidicly

coupling the radial passages 415c and 415d. As a result fluidic materials within the tubular support member 415 may not pass into the annulus between the tubular support member and the tubular member 120.

As a result of the forward axial displacement of the resilient dog 435e, the outside diameter of the expansion cone segments 425 is now greater than the inside diameter of expandable tubular member 120 thereby permitting the apparatus 400 to be used to radially expand and plastically deform the tubular member, and fluidic materials within the interior 415a of the tubular support member 415 may no longer pass through the radial passages, 415d and 455ed, into the annulus between the apparatus 400 and the tubular member thereby permitting the interior of the apparatus to be pressurized.

The apparatus 400 may then be operated to radially expand and plastically deform the tubular member 120 by applying an upward axial force to the tubular support member 415 and/or by injecting a pressurized fluidic material into the tubular support member.

In particular, as illustrated in Figs. 8 and 8a-8d, the expandable tubular member 120 may then be radially expanded using the apparatus 400 by injecting a fluidic material 275 into the apparatus through the passages 405a, 310a, 415a, and 420a. The injection of the fluidic material 275 may pressurize the interior 120a of the expandable tubular member 120. In addition, because the packer cup assemblies, 440 and 450, seal off an annular region 120aa below the packer cup assemblies between the expandable tubular member 120 and the tubular support member 415, the injection of the fluidic material 275 may also pressurize the annular region.

The continued injection of the fluidic material 275 may then pressurize the interior 120a of the expandable tubular member 120 thereby plastically deforming and radially expanding the expandable tubular member off of the expansion cone segments 425. Because the outer surfaces, 425bb and 425bc, of the expansion cone segments 425 are tapered, the plastic deformation and radial expansion of the expandable tubular member 120 proximate the expansion cone segments is facilitated. Furthermore, in an exemplary embodiment, the continued injection of the fluidic material 275 also pressurizes the annular region 120aa defined between the interior surface of the expandable tubular member 120 and the exterior surface of the tubular support member 415 that is bounded on the upper end by the packer cup assembly 440 and on the lower end by the expansion cone segments 425. Furthermore, in an exemplary embodiment, the pressurization of the annular region 120aa also radially expands at least a portion of the surrounding portion of the expandable tubular member

120. In this manner, the plastic deformation and radial expansion of the expandable tubular member 120 is enhanced. Furthermore, during operation of the apparatus 300, the packer cup assemblies 440 and 450 prevent the pressurized fluidic material 275 from passing above and beyond the packer cup assemblies and thereby define the length of the pressurized annular region 120aa. In an exemplary embodiment, the pressurization of the annular region 120aa decreases the operating pressures required for plastic deformation and radial expansion of the expandable tubular member 120 by as much as 50% and also reduces the angle of attack of the tapered external surfaces, 425bb and 425bc, of the expansion cone segments 425.

The radial expansion of the expandable tubular member 120 may then continue until the upper end 120b of the expandable tubular member is radially expanded and plastically deformed along with the overlapping portion of the wellbore casing 110. Because the expansion cone segments 425 may be adjustably positioned from an outside diameter less than the inside diameter of the expandable tubular member 120 to an outside diameter substantially equal to the inside diameter of the pre-existing casing 110, the resulting wellbore casing, including the casing 110 and the radially expanded tubular member 120, created by the operation of the apparatus 400 may have a single substantially constant inside diameter thereby providing a mono-diameter wellbore casing.

During the radial expansion process, the expansion cone segments 425 may be raised out of the expanded portion of the tubular member 120 by applying an upward axial force to the tubular support member 415. In a preferred embodiment, during the radial expansion process, the expansion cone segments 425 are raised at approximately the same rate as the tubular member 120 is expanded in order to keep the tubular member stationary relative to the new wellbore section 115.

In a preferred embodiment, when the upper end portion of the expandable tubular member 120 and the lower portion of the wellbore casing 110 that overlap with one another are plastically deformed and radially expanded by the expansion cone segments 425, the expansion cone segments are displaced out of the wellbore 100 by both the operating pressure within the interior of the tubular member 120 and a upwardly directed axial force applied to the tubular support member 405.

In a preferred embodiment, the operating pressure and flow rate of the fluidic material 275 is controllably ramped down when the expansion cone segments 425 reach the upper end portion of the expandable tubular member 120. In this manner, the sudden release of pressure caused by the complete radial expansion and plastic deformation of the expandable tubular member 120 off of the expansion cone

segments 425 can be minimized. In a preferred embodiment, the operating pressure is reduced in a substantially linear fashion from 100% to about 10% during the end of the extrusion process beginning when the expansion cone segments 425 are within about 5 feet from completion of the extrusion process.

Alternatively, or in combination, the wall thickness of the upper end portion of the expandable tubular member 120 is tapered in order to gradually reduce the required operating pressure for plastically deforming and radially expanding the upper end portion of the tubular member. In this manner, shock loading of the apparatus is at least reduced.

Alternatively, or in combination, a shock absorber is provided in the tubular support member 405 in order to absorb the shock caused by the sudden release of pressure. The shock absorber may comprise, for example, any conventional commercially available shock absorber, bumper sub, or jars adapted for use in wellbore operations.

Alternatively, or in combination, an expansion cone catching structure is provided in the upper end portion of the expandable tubular member 120 in order to catch or at least decelerate the expansion cone segments 425.

Alternatively, or in combination, during the radial expansion process, an upward axial force is applied to the tubular support member 415 sufficient to plastically deform and radially expand the tubular member 120 off of the external surfaces, 225bb and 225bc, of the expansion cone segments 425.

Alternatively, or in combination, in order to facilitate the pressurization of the interior 120a of the expandable tubular member by the injection of the fluidic materials 275, the region within the wellbore section 115 below the apparatus 400 may be fluidicly sealed off in a convention manner using, for example, a packer.

Once the radial expansion process is completed, the tubular support member 405, the tubular support member 410, the tubular support member 415, the end stop 420, the expansion cone segments 425, the split ring collar 430, the dog assembly 435, the packer cup assembly 440, the spacer 445, the packer cup assembly 450, and the dog assembly 455 are removed from the wellbores 100 and 115.

Referring now to Figs. 9, 9a, 10 and 10a, an embodiment of an adjustable expansion cone assembly 500 will be described. The assembly 500 includes a tubular support member 505 that defines a passage 505a and includes a flange 505b, an expansion cone support flange assembly 505c, and an end stop 505d. The expansion cone support flange assembly 505c includes a tubular body 505ca and a plurality of equally spaced apart expansion cone segment support members 505cb that extend

outwardly from the tubular body in the radial direction that each include identical bases 505cba and extensions 505cbb. The support members 505cb further include first sections 505cbc having arcuate conical outer surfaces and second sections 505cbd having arcuate cylindrical outer surfaces for reasons to be described.

An expansion cone segment assembly 510 is provided that includes a tubular support 510a defining a passage 510aa for receiving the tubular support member 505 and a slot 510ab. A plurality of spaced apart and substantially identical resilient expansion cone segment collets 510b extend from the tubular support 510a in the axial direction that include expansion cone segments 510ba extending therefrom in the axial direction. Each of the expansion cone segments 510ba further include arcuate conical expansion surfaces 510baa for radially expanding an expandable tubular member.

A split ring collar 515 is provided that defines a passage 515a for receiving the tubular support member 505 that includes an L-shaped retaining member 515b at one end for mating with the slot 510ab of the tubular support 510a of the expansion cone segment assembly 510. Another end of the split ring collar 515 includes an L-shaped retaining member 515c. A tubular sleeve 520 is provided that defines a passage 520a for receiving the tubular support member 505 that includes a slot 520b for receiving the L-shaped retaining member 515c of the split ring collar 515.

During operation of the assembly 500, as illustrated in Figs. 9 and 9a, in an unexpanded position, the expansion cone segments 510ba of the expansion cone segment assembly 510 are positioned adjacent to the base of the conical section 505cbc of the expansion cone segment support members 505cb with the outside diameter of the expansion cone segments less than or equal to the maximum outside diameter of the assembly. As illustrated in Figs. 10 and 10a, the assembly 500 may then be expanded by displacing the tubular sleeve 520, the split ring collar 515, and the expansion cone segment assembly 510 in the axial direction towards the expansion cone segment support members 505cb. As a result, the expansion cone segments 510ba are driven up the conical section 505cbc of the expansion cone segment support members 505cb and then onto the cylindrical section 505cbd of the expansion cone segment support members until the expansion cone segments impact the end stop 505d. In this manner, the outside diameter of the expansion segments 510ba is greater than the maximum diameter of the remaining components of the assembly 500. Furthermore, the conical outer surfaces 510baa of the expansion cone segments 510ba may now be used to radially expand a tubular member. Note that the extensions 505cbb of the expansion cone segment support members 505cb provide support in the circumferential direction to the adjacent expansion cone segments

510ba. In an exemplary embodiment, the outer conical surfaces 510baa of the expansion cone segments 510ba in the expanded position of the assembly 500 provide a substantially continuous outer conical surfaces in the circumferential direction.

The assembly 500 may then be returned to the unexpanded position by displacing the tubular sleeve 520, the split ring collar 515, and the expansion cone segment assembly 510 in the axial direction away from the expansion cone segment support members 505cb. As a result, the expansion cone segments 510ba are displaced off of the cylindrical section 505cbd and the conical section 505cbc of the expansion cone segment support members 505cb. Because the collets 510b of the expansion cone segment assembly 510 are resilient, the expansion segments 510ba are thereby returned to a position in which the outside diameter of the expansion cone segments is less than or equal to the maximum diameter of the remaining components of the assembly 500.

In several alternative embodiments, the assembly 500 is incorporated into the assemblies 200, 300 and/or 400.

Referring now to Figs. 11, 11a, 12 and 12a, an embodiment of an adjustable expansion cone assembly 600 will be described. The assembly 600 includes a tubular support member 605 that defines a passage 605a and includes an expansion cone support flange assembly 605b, and an end stop 605c. The expansion cone support flange assembly 605b includes a tubular body 605ba and a plurality of equally spaced apart expansion cone segment substantially identical support members 605bb that extend outwardly from the tubular body in the radial direction. The support members 605bb further include first sections 605bba having arcuate cylindrical outer surfaces, second sections 605bbb having arcuate conical outer surfaces, and third sections 605bbc having arcuate cylindrical outer surfaces for reasons to be described.

An expansion cone segment assembly 610 is provided that includes a tubular support 610a defining a passage 610aa for receiving the tubular support member 605 and a slot 610ab. A plurality of spaced apart and substantially identical resilient expansion cone segment collets 610b extend from the tubular support 610a in the axial direction that include expansion cone segments 610ba extending therefrom in the axial direction. Each of the expansion cone segments 610ba further include arcuate conical expansion surfaces 610baa for radially expanding an expandable tubular member.

A split ring collar 615 is provided that defines a passage 615a for receiving the tubular support member 605 that includes an L-shaped retaining member 615b at one end for mating with the slot 610ab of the tubular support 610a of the expansion cone segment assembly 610. Another end of the split ring collar 615 includes an L-shaped

retaining member 615c. A tubular sleeve 620 is provided that defines a passage 620a for receiving the tubular support member 605 that includes a slot 620b for receiving the L-shaped retaining member 615c of the split ring collar 615.

During operation of the assembly 600, as illustrated in Figs. 11 and 11a, in an unexpanded position, the expansion cone segments 610ba of the expansion cone segment assembly 610 are positioned on the cylindrical section 605bba, adjacent to the base of the conical section 605bbb, of the expansion cone segment support members 605bb with the outside diameter of the expansion cone segments less than or equal to the maximum outside diameter of the assembly. As illustrated in Figs. 12 and 12a, the assembly 600 may then be expanded by displacing the tubular sleeve 620, the split ring collar 615, and the expansion cone segment assembly 610 in the axial direction towards the expansion cone segment support members 605bb. As a result, the expansion cone segments 610ba are driven up the conical section 605bbb of the expansion cone segment support members 605bb and then onto the cylindrical section 605bbc of the expansion cone segment support members until the expansion cone segments impact the end stop 605c. In this manner, the outside diameter of the expansion segments 610ba is greater than the maximum diameter of the remaining components of the assembly 600. Furthermore, the conical outer surfaces 610baa of the expansion cone segments 610ba may now be used to radially expand a tubular member. In an exemplary embodiment, the outer conical surfaces 610baa of the expansion cone segments 610ba in the expanded position of the assembly 600 provide a substantially continuous outer conical surfaces in the circumferential direction.

The assembly 600 may then be returned to the unexpanded position by displacing the tubular sleeve 620, the split ring collar 615, and the expansion cone segment assembly 610 in the axial direction away from the expansion cone segment support members 605bb. As a result, the expansion cone segments 610ba are displaced off of the cylindrical section 605bbc and the conical section 605bbb and back onto the cylindrical section 605bba of the expansion cone segment support members 605bb. Because the collets 610b of the expansion cone segment assembly 610 are resilient, the expansion segments 610ba are thereby returned to a position in which the outside diameter of the expansion cone segments is less than or equal to the maximum diameter of the remaining components of the assembly 600.

In several alternative embodiments, the assembly 600 is incorporated into the assemblies 200, 300 and/or 400.

Referring now to Figs. 13, 13a, 13b, 13c, 14 and 14a, an embodiment of an adjustable expansion cone assembly 700 will be described. The assembly 700

includes a tubular support member 705 that defines a passage 705a and includes an expansion cone support flange assembly 705b, and an end stop 705c. The expansion cone support flange assembly 705b includes a tubular body 705ba and a plurality of equally spaced apart expansion cone segment substantially identical support members 705bb that extend outwardly from the tubular body in the radial direction. The support members 705bb further include first sections 705bba having arcuate cylindrical outer surfaces, second sections 705bbb having arcuate conical outer surfaces, and third sections 705bbc having arcuate cylindrical outer surfaces for reasons to be described.

An expansion cone segment assembly 710 is provided that includes a first tubular support 710a defining a passage 710aa for receiving the tubular support member 705 that includes a slot 710ab and a second tubular support 710b defining a passage 710ba for receiving the tubular support member 705 that includes a plurality of spaced apart and substantially identical axial slots 710bb. A plurality of spaced apart and substantially identical resilient expansion cone segment collets 710ac extend from the first tubular support 710a in the axial direction and are received within corresponding ones of the axial slots 710bb in the second tubular support 710b that include substantially identical expansion cone segments 710aca extending therefrom in the axial direction. A plurality of spaced apart and substantially identical resilient expansion cone segment collets 710bc extend from the second tubular support 710b in the axial direction that are interleaved and overlap with the expansion cone segment collets 710ac and that include substantially identical expansion cone segments 710bca extending therefrom in the axial direction. Each of the expansion cone segments, 710aca and 710bca, further include arcuate conical expansion surfaces, 710acaa and 710bcaa, respectively, foı radially expanding an expandable tubular member. A plurality of pins 715a-715d couple the expansion cone segment collets 710ac to the second tubular support 710b.

A split ring collar 720 is provided that defines a passage 720a for receiving the tubular support member 705 that includes an L-shaped retaining member 720b at one end for mating with the slot 710ab of the first tubular support 710a of the expansion cone segment assembly 710. Another end of the split ring collar 720 includes an L-shaped retaining member 720c. A tubular sleeve 725 is provided that defines a passage 725a for receiving the tubular support member 705 that includes a slot 725b for receiving the L-shaped retaining member 720c of the split ring collar 720.

During operation of the assembly 700, as illustrated in Figs. 13, 13a, 13b, and 13c, in an unexpanded position, the expansion cone segments 710aca of the expansion cone segment assembly 710 overlap with and are positioned over the

expansion cone segments 710bca of the expansion cone segment assembly, adjacent to the base of the conical section 705bbb, of the expansion cone segment support members 705bb with the outside diameter of the expansion cone segments less than or equal to the maximum outside diameter of the assembly. As illustrated in Figs. 14 and 14a, the assembly 700 may then be expanded by displacing the tubular sleeve 725, the split ring collar 720, and the expansion cone segment assembly 710 in the axial direction towards the expansion cone segment support members 705bb. As a result, the expansion cone segments, 710aca and 710bca, are driven up the conical section 705bbb of the expansion cone segment support members 705bb and then onto the cylindrical section 705bbc of the expansion cone segment support members until the expansion cone segments impact the end stop 705c. In this manner, the outside diameter of the expansion segments, 710aca and 710bca, is greater than the maximum diameter of the remaining components of the assembly 700. Furthermore, the conical outer surfaces, 710acaa and 710bcaa, of the expansion cone segments, 710aca and 710bca, respectively, may now be used to radially expand a tubular member. In an exemplary embodiment, the outer conical surfaces, 710acaa and 710bcaa, of the expansion cone segments, 710aca and 710bca, respectively, in the expanded position of the assembly 700 provide a substantially continuous outer conical surfaces in the circumferential direction.

The assembly 700 may then be returned to the unexpanded position by displacing the tubular sleeve 720, the split ring collar 715, and the expansion cone segment assembly 710 in the axial direction away from the expansion cone segment support members 705bb. As a result, the expansion cone segments, 710aca and 710bca, are displaced off of the cylindrical section 705bbc and the conical section 705bbb and back onto the cylindrical section 705bba of the expansion cone segment support members 705bb. Because the collets, 710ac and 710bc, of the expansion cone segment assembly 710 are resilient, the expansion segments, 710aca and 710bca, are thereby returned to a position in which the outside diameter of the expansion cone segments is less than or equal to the maximum diameter of the remaining components of the assembly 700.

In several alternative embodiments, the assembly 700 is incorporated into the assemblies 200, 300 and/or 400.

Referring to Figs. 15 and 15a-15j, an alternative embodiment of an apparatus 800 for forming a wellbore casing in a subterranean formation will now be described. The apparatus 800 includes a tubular support member 805 defining an internal passage 805a that is coupled to an end of a tubular coupling 810 defining an internal

passage 810a. The other end of the tubular coupling 810 is coupled to an end of a tubular support member 815 defining an internal passage 815a having a throat passage 815aa that includes a first radial passage 815b, a first flange 815c having a second radial passage 815d, a second flange 815e having opposite shoulders, 815ea and 815eb, a third flange 815f, and an expansion cone support body 815g. The other end of the tubular support member 815 is coupled to a tubular end stop 820 that defines a passage 820a.

As illustrated in Figs. 15d and 15e, the expansion cone support body 815g includes a first end 815ga, a tapered hexagonal portion 815gb that includes a plurality of T-shaped slots 815gba provided on each of the external faceted surfaces of the tapered hexagonal portion, and a second end 815gc. In an exemplary embodiment, the angle of attack of the tapered hexagonal portion 815gb ranges from about 35 to 50 degrees for reasons to be described.

As illustrated in Figs. 15, 15a-15c, and 15f-15j, a plurality of expansion cone segments 825 are provided that include first ends 825a that include T-shaped retaining members 825aa and second ends 825b that include T-shaped retaining members 825ba that mate with and are received within corresponding T-shaped slots 815gba on the tapered hexagonal portion 815gb of the expansion cone support body 815g, first external surfaces 825bb, second external surfaces 825bc, and third external surfaces 825bd. Thus, in an exemplary embodiment, a total of six expansion cone segments 825 are provided that are slidably coupled to corresponding sides of the tapered hexagonal portion 815gb of the expansion cone support body 815g.

In an exemplary embodiment, the widths of the first external surfaces 825bb of the expansion cone segments 825 increase in the direction of the second external surfaces 825bc, the widths of the second external surfaces are substantially constant, and the widths of the third external surfaces 825bd decrease in the direction of the first ends 825a of the expansion cone segments for reasons to be described. In an exemplary embodiment, the first external surfaces 825bb of the expansion cone segments 825 taper upwardly in the direction of the second external surfaces 825bc, the second external surfaces taper upwardly in the direction of the third external surfaces 825bd, and the third external surfaces 825bd taper downwardly in the direction of the first ends 825a of the expansion cone segments for reasons to be described. In an exemplary embodiment, the angle of attack of the taper of the first external surfaces 825bb of the expansion cone segments 825 are greater than the angle of attack of the taper of the second external surfaces 825bc. In an exemplary embodiment, the first and second external surfaces, 825bb and 825bc, of the

expansion cone segments 825 are arcuate such that when the expansion cone segments 825 are displaced in the direction of the end stop 420, the first and second external surfaces of the expansion cone segments provide a substantially continuous outer circumferential surface for reasons to be described.

As illustrated in Fig. 15i, in an exemplary embodiment, the external surfaces, 825bb, 825bc, and 825bd, of the second ends 825b of the expansion cone segments 825 are adapted to mate with one another in order to interlock adjacent expansion cone segments.

A split ring collar 830 that defines a passage 830a for receiving the tubular support member 815 is provided that includes a first end that includes plurality of T-shaped slots 830b for receiving and mating with corresponding T-shaped retaining members 825aa of the expansion cone segments 825 and a second end that includes an L-shaped retaining member 830c.. In an exemplary embodiment, the split ring collar 830 is a conventional split ring collar commercially available from Halliburton Energy Services modified in accordance with the teachings of the present disclosure.

A dog assembly 835 is provided that includes a tubular sleeve 835a that defines a passage 835aa for receiving the tubular support member 815 and includes a slot 835ab for receiving and mating with the L-shaped retaining member 830c of the split ring collar 830, a counterbore 835ac, and a radial passage 835ad. An end of a load transfer pin 835b passes through the radial passage 835ad and is coupled to a retaining ring 835c that defines a passage 835ca for receiving the flange 815f of the tubular support member 815 and is received within the counterbore 835ac of the tubular sleeve. A ring 835d that defines a passage 835da for receiving the tubular support member 815 and a spring 835e are also received within the counterbore 835ac of the tubular sleeve 835a between the flange 815f and the end of the counterbore. The other end of the load transfer pin 835b is coupled to an end of a tubular sleeve 835f that includes a counterbore 835fa for receiving the tubular sleeve 835a, a radial passage 835fb for receiving a conventional resilient dog 835g, a counterbore 835fc for receiving and mating with the flange 815e of the tubular support member 815, a flange 835fd, and a flange 835fe including counterbores, 835ff and 835fg, that mate with and receive the flange 815c of the tubular support member, and a radial passage 835fh.

A first conventional packer cup assembly 840 that defines a passage 440a for receiving the tubular sleeve 835f includes a first end 840b that mates with the flange 835fd of the tubular sleeve 835f, a conventional sealing cup 840c, and a second end 840d. A tubular spacer 845 that defines a passage 845a for receiving the tubular sleeve 835f includes a first end 845b that mates with the second end 840d of the first

packer cup assembly 840 and a second end 845c. A second conventional packer cup assembly 850 that defines a passage 850a for receiving the tubular sleeve 835f includes a first end 850b that mates with the second end 845c of the spacer 845, a conventional sealing cup 850c, and a second end 850d that mates with the flange 835fe of the tubular sleeve.

In an exemplary embodiment, during operation of the apparatus 800, as illustrated in Figs. 15 and 15a-15j, the apparatus may be initially positioned in the wellbore 100, within the casing 110, with the dog assembly 835 positioned in a neutral position in which the radial passage 815d of the tubular support member 815 is fluidicly coupled to the radial passage 835fh of the dog assembly 835 and the expansion cone segments 825 are not driven up the tapered hexagonal portion 815gb of the expansion cone support body 815g of the tubular support member 815 into contact with the stop member 320. In this manner, fluidic materials within the interior 815a of the tubular support member 815 may pass through the radial passages, 815d and 835fh, into the annulus between the apparatus 800 and the casing 110 thereby preventing over pressurization of the annulus. Furthermore, in this manner, the outside diameter of the expansion cone segments 825 is less than or equal to the outside diameter of the stop member 820 thereby permitting the apparatus 800 to be displaced within the casing 110.

As illustrated in Figs. 16, and 16a-16c, the apparatus 800 may then be positioned in the tubular member 120. During the insertion of the apparatus into the tubular member 120, the upper end 120b of the tubular member may impact the end of the resilient dog 835g of the dog assembly 835 thereby driving the resilient dog 835g backwards onto the shoulder 815ea of the flange 815e of the tubular support member 815. As a result of the backward axial displacement of the resilient dog 835g, the tubular sleeve 835f, the pin 835b, the retaining ring 835c, the ring 835d, and the spring 835e of the dog assembly 835 are driven backward thereby compressing the spring 835e and applying an axial biasing force to the tubular sleeve 835a that prevents the expansion cone segments 825 from being displaced toward the end stop 820.

The apparatus 800 may then be at least partially positioned in the open hole section 115a of the wellbore section 115, beyond the lower end 120c of the tubular member 120. In an exemplary embodiment, that portion of the apparatus 800 that includes the stop member 820, the expansion cone segments 825, the split ring collar 830, and the dog assembly 835 is then positioned in the open hole section 115a of the wellbore section 115, beyond the lower end 120 of the tubular member for reasons to be described. Because the dog 835g of the dog assembly 835 is resilient, once the

apparatus 800 has been positioned in the open hole section 115a of the wellbore section 115, beyond the lower end 120c of the tubular member 120, the resilient dog of the dog assembly may spring outwardly in the radial direction.

The apparatus 800 may then be repositioned at least partially back within the tubular member 120. During the re-insertion of the apparatus into the tubular member 120, the lower end 120c of the tubular member may impact the ends of the resilient dog 835g of the dog assembly 835 thereby driving the resilient dog forward until the resilient dog is positioned onto the shoulder 815eb of the flange 815e of the tubular support member 815.

As a result of the forward axial displacement of the resilient dog 835g, the tubular sleeve 835f, the spring 835e, the ring 835d, the ring 835c, the pin 835b, and the tubular sleeve 835a are displaced in the forward axial direction thereby also displacing the split ring collar 830 and the expansion cone segments 825 in the forward axial direction. As a result, the expansion cone segments 825 are driven up the tapered hexagonal portion 815gb of the expansion cone support body 815g of the tubular support member 815 into contact with the stop member 320. Furthermore, as a result of the forward axial displacement of the tubular sleeve 835f, the radial passages, 815d and 835fh, are fluidicly decoupled. As a result fluidic materials within the tubular support member 815 may not pass into the annulus between the tubular support member and the tubular member 120.

As a result of the forward axial displacement of the resilient dog 435e, the outside diameter of the expansion cone segments 825 is now greater than the inside diameter of expandable tubular member 120 thereby permitting the apparatus 800 to be used to radially expand and plastically deform the tubular member, and fluidic materials within the interior 815a of the tubular support member 815 may no longer pass through the radial passages, 815d and 455ed, into the annulus between the apparatus 800 and the tubular member thereby permitting the interior of the apparatus to be pressurized.

The apparatus 800 may then be operated to radially expand and plastically deform the tubular member 120 by applying an upward axial force to the tubular support member 815 and/or by injecting a pressurized fluidic material into the tubular support member.

In particular, as illustrated in Figs. 17 and 17a-17c, the expandable tubular member 120 may then be radially expanded using the apparatus 800 by injecting a fluidic material 275 into the apparatus through the passages 805a, 810a, 815a, and 820a. The injection of the fluidic material 275 may pressurize the interior 120a of the

expandable tubular member 120. In addition, because the packer cup assemblies, 840 and 850, seal off an annular region 120aa below the packer cup assemblies between the expandable tubular member 120 and the tubular support member 815, the injection of the fluidic material 275 may also pressurize the annular region.

The continued injection of the fluidic material 275 may then pressurize the interior 120a of the expandable tubular member 120 thereby plastically deforming and radially expanding the expandable tubular member off of the expansion cone segments 825. Because the outer surfaces, 825bb and 825bc, of the expansion cone segments 825 are tapered, the plastic deformation and radial expansion of the expandable tubular member 120 proximate the expansion cone segments is facilitated. Furthermore, in an exemplary embodiment, the continued injection of the fluidic material 275 also pressurizes the annular region 120aa defined between the interior surface of the expandable tubular member 120 and the exterior surface of the tubular support member 815 that is bounded on the upper end by the packer cup assembly 840 and on the lower end by the expansion cone segments 825. Furthermore, in an exemplary embodiment, the pressurization of the annular region 120aa also radially expands at least a portion of the surrounding portion of the expandable tubular member 120. In this manner, the plastic deformation and radial expansion of the expandable tubular member 120 is enhanced. Furthermore, during operation of the apparatus 300, the packer cup assemblies 840 and 850 prevent the pressurized fluidic material 275 from passing above and beyond the packer cup assemblies and thereby define the length of the pressurized annular region 120aa. In an exemplary embodiment, the pressurization of the annular region 120aa decreases the operating pressures required for plastic deformation and radial expansion of the expandable tubular member 120 by as much as 50% and also reduces the angle of attack of the tapered external surfaces, 825bb and 825bc, of the expansion cone segments 825.

The radial expansion of the expandable tubular member 120 may then continue until the upper end 120b of the expandable tubular member is radially expanded and plastically deformed along with the overlapping portion of the wellbore casing 110. Because the expansion cone segments 825 may be adjustably positioned from an outside diameter less than the inside diameter of the expandable tubular member 120 to an outside diameter substantially equal to the inside diameter of the pre-existing casing 110, the resulting wellbore casing, including the casing 110 and the radially expanded tubular member 120, created by the operation of the apparatus 800 may have a single substantially constant inside diameter thereby providing a mono-diameter wellbore casing.

During the radial expansion process, the expansion cone segments 825 may be raised out of the expanded portion of the tubular member 120 by applying an upward axial force to the tubular support member 815. In a preferred embodiment, during the radial expansion process, the expansion cone segments 825 are raised at approximately the same rate as the tubular member 120 is expanded in order to keep the tubular member stationary relative to the new wellbore section 115.

In a preferred embodiment, when the upper end portion of the expandable tubular member 120 and the lower portion of the wellbore casing 110 that overlap with one another are plastically deformed and radially expanded by the expansion cone segments 825, the expansion cone segments are displaced out of the wellbore 100 by both the operating pressure within the interior of the tubular member 120 and a upwardly directed axial force applied to the tubular support member 405.

In a preferred embodiment, the operating pressure and flow rate of the fluidic material 275 is controllably ramped down when the expansion cone segments 825 reach the upper end portion of the expandable tubular member 120. In this manner, the sudden release of pressure caused by the complete radial expansion and plastic deformation of the expandable tubular member 120 off of the expansion cone segments 825 can be minimized. In a preferred embodiment, the operating pressure is reduced in a substantially linear fashion from 100% to about 10% during the end of the extrusion process beginning when the expansion cone segments 825 are within about 5 feet from completion of the extrusion process.

Alternatively, or in combination, the wall thickness of the upper end portion of the expandable tubular member 120 is tapered in order to gradually reduce the required operating pressure for plastically deforming and radially expanding the upper end portion of the tubular member. In this manner, shock loading of the apparatus is at least reduced.

Alternatively, or in combination, a shock absorber is provided in the tubular support member 805 in order to absorb the shock caused by the sudden release of pressure. The shock absorber may comprise, for example, any conventional commercially available shock absorber, bumper sub, or jars adapted for use in wellbore operations.

Alternatively, or in combination, an expansion cone catching structure is provided in the upper end portion of the expandable tubular member 120 in order to catch or at least decelerate the expansion cone segments 825.

Alternatively, or in combination, during the radial expansion process, an upward axial force is applied to the tubular support member 815 sufficient to plastically deform

and radially expand the tubular member 120 off of the external surfaces, 225bb and 225bc, of the expansion cone segments 825.

Alternatively, or in combination, in order to facilitate the pressurization of the interior 120a of the expandable tubular member by the injection of the fluidic materials 275, the region within the wellbore section 115 below the apparatus 800 may be fluidicly sealed off in a convention manner using, for example, a packer.

Once the radial expansion process is completed, the tubular support member 805, the tubular support member 810, the tubular support member 815, the end stop 820, the expansion cone segments 825, the split ring collar 830, the dog assembly 835, the packer cup assembly 840, the spacer 845, and the packer cup assembly 850 are removed from the wellbores 100 and 115.

If the expansion cone segments 825 become lodged within the expandable tubular member 120 during the radial expansion process, then a ball 280 may be placed in the throat 815aa of the passage 815a of the tubular support member 815. The continued injection of the fluidic material 275 following the placement of the ball 280 in the throat 815aa of the passage 815a of the tubular support member will then pressurize the radial passage 815b and an annular portion 835fga of the counterbore 835fg. As a result of the pressurization of the annular portion 835fga of the counterbore 835fg, the tubular sleeve 835f, the pin 835b, the retaining ring 835c, the ring 835d, the spring 835e, and the tubular sleeve 835a of the dog assembly 835, and the split ring collar 830 are driven backward thereby displacing the expansion cone segments 825 backwards in the axial direction away from the end stop 820. In this manner, the outside diameter of the expansion cone segments 825 is thereby reduced and the apparatus 800 may then be removed from the expandable tubular member 120.

Referring now to Figs. 18a, 18b, 18c, and 18d, an embodiment of an adjustable expansion cone assembly 900 will be described. The assembly 900 includes a tubular support member 905 that defines a passage 905a and includes an expansion cone support flange assembly 905b that is coupled to an end stop 910 that defines a passage 910a. The expansion cone support flange assembly 905b includes a first tubular end 905ba, a second tubular end 905bb, and an intermediate hexagonal conical tubular body 905bc that includes a plurality of substantially identical and equally spaced apart expansion cone segment support slots 905bcaa-905bcaf on each of the facets of the hexagonal tubular body.

A plurality of first expansion cone segments 915a-915c are provided that include T-shaped retaining members 915aa-915ca that mate with and are movably

received within the T-shaped slots 905bcaa, 905bcac, and 905bcae of the hexagonal conical tubular body 905bc of the expansion cone support assembly 905b, T-shaped retaining members 915ab-915cb, exterior top surfaces 915ac-915cc, exterior top surfaces 915ad-915cd, exterior top surfaces 915ae-915ce, exterior top surfaces 915af-915cf, and exterior top surfaces 915ag-915cg. In an exemplary embodiment, the exterior top surfaces 915ac-915cc and the exterior top surfaces 915ad-915cd are arcuate conical surfaces in which the angle of attack of the exterior top surfaces 915ac-915cc is greater than the angle of attack of the exterior top surfaces 915ad-915cd.

A plurality of second expansion cone segments 920a-920c, that are interleaved with and complementary shaped to the first expansion cone segments 915a-915c, are also provided that include T-shaped retaining members 920aa-920ca that mate with and are movably received within the T-shaped slots 905bcab, 905bcad, and 905bcaf of the hexagonal conical tubular body 905bc of the expansion cone support assembly 905b, T-shaped retaining members 920ab-920cb, exterior top surfaces 920ac-920cc, exterior top surfaces 920ad-920cd, exterior top surfaces 920ae-920ce, exterior top surfaces 920af-920cf, and exterior top surfaces 920ag-920cg. In an exemplary embodiment, the exterior top surfaces 920ac-920cc and the exterior top surfaces 920ad-920cd are arcuate conical surfaces in which the angle of attack of the exterior top surfaces 920ac-920cc is greater than the angle of attack of the exterior top surfaces 920ad-920cd.

A split ring collar 925 is provided that defines a passage 925a for receiving the tubular support member 905 that includes an L-shaped retaining member 925b at one end and another end of the split ring collar 925 includes T-shaped slots, 925c, 925d, 925e, 925f, 925g, and 925h, for mating with and receiving the T-shaped retaining members, 915ab, 920ab, 915bb, 920bb, 915cb, and 920cb, of the expansion cone segments, 915a, 920a, 915b, 920b, 915c, and 920c, respectively. A tubular sleeve 930 is provided that defines a passage 930a for receiving the tubular support member 905 and that also includes a slot 930b for receiving and mating with the L-shaped retaining member 925b of the split ring collar 925.

During operation of the assembly 900, as illustrated in Figs. 18a, 18b, 18c, and 18d, in an unexpanded position, the expansion cone segments, 915a, 915b, 915c, 915d, 920a, 920b, 920c, and 920d are positioned adjacent to the base of the hexagonal conical tubular body 905bc of the expansion cone support flange 905b away from the end stop 910. In this manner, the outside diameter of the expansion cone segments is less than or equal to the maximum outside diameter of the assembly. Furthermore, in the unexpanded position, the expansion cone segments, 915a, 915b,

and 915c, are positioned further away from the end stop 910 than the expansion cone segments, 920a, 920b, and 920c.

As illustrated in Figs. 19 and 19a, the assembly 900 may then be expanded by displacing the tubular sleeve 930 and the split ring collar 925 in the axial direction towards the expansion cone segment support members 705bb. As a result, the expansion cone segments, 915a, 915b, 915c, 920a, 920b, 920c, are driven up the hexagonal conical tubular body 905bc of the expansion cone support flange 905b until the expansion cone segments impact the end stop 910. In this manner, the outside diameter of the expansion segments, 915a, 915b, 915c, 920a, 920b, and 920c, is greater than the maximum diameter of the remaining components of the assembly 900. Furthermore, the conical outer surfaces, 915ac, 915bc, 915cc, 920ac, 920bc, and 920cc, and the conical outer surfaces, 915ad, 915bd, 915cd, 920ad, 920bd, and 920cd of the expansion cone segments, 915a, 915b, 915c, 920a, 920b, and 920c, respectively, may now be used to radially expand a tubular member. In an exemplary embodiment, the outer conical surfaces, 915ac, 915bc, 915cc, 920ac, 920bc, and 920cc, and the conical outer surfaces, 915ad, 915bd, 915cd, 920ad, 920bd, and 920cd of the expansion cone segments, 915a, 915b, 915c, 920a, 920b, and 920c, respectively, in the expanded position of the assembly 900, provide a substantially continuous outer conical surfaces in the circumferential direction. Furthermore, note that in the expanded position of the assembly 900, the first set of expansion cone segments, 915a, 915b, and 915c, are brought into alignment with the second set of expansion cone segments, 920a, 920b, and 920c.

The assembly 900 may then be returned to the unexpanded position by displacing the tubular sleeve 930 and the split ring collar 925 in the axial direction away from the end stop 910. As a result, the expansion cone segments, 915a, 915b, 915c, 920a, 920b, and 920c, are displaced away from the end top 910, down the conical hexagonal tubular member 905bc and thereby are returned to a position in which the outside diameter of the expansion cone segments is less than or equal to the maximum diameter of the remaining components of the assembly 900.

In several alternative embodiments, the assembly 900 is incorporated into the assemblies 200, 300, 400, and 800.

Referring to Fig. 20a, an embodiment of an expansion cone segment assembly 1000 includes interlocking expansion cone segments, 1000a, 1000b, 1000c, 1000d, 1000e, and 1000f.

Referring to Fig. 20b, an embodiment of an expansion cone segment assembly 1100 includes interlocking expansion cone segments, 1100a, 1100b, 1100c, 1100d, 1100e, and 1100f.

Referring to Fig. 20c, an embodiment of an expansion cone segment assembly 1200 includes interlocking expansion cone segments, 1200a, 1200b, 1200c, 1200d, 1200e, and 1200f.

Referring to Fig. 20d, an embodiment of an expansion cone segment assembly 1300 includes interlocking expansion cone segments, 1300a, 1300b, 1300c, 1300d, 1300e, and 1300f.

Referring to Fig. 20e, an embodiment of an expansion cone segment assembly 1400 includes interlocking expansion cone segments, 1400a, 1400b, 1400c, 1400d, 1400e, and 1400f.

Referring to Fig. 20f, an embodiment of an expansion cone segment assembly 1500 includes interlocking expansion cone segments, 1500a, 1500b, 1500c, 1500d, 1500e, and 1500f.

Referring to Fig. 20g, an embodiment of an expansion cone segment assembly 1600 includes interlocking expansion cone segments, 1600a, 1600b, 1600c, 1600d, 1600e, and 1600f.

Referring to Fig. 20h, an embodiment of an expansion cone segment assembly 1700 includes interlocking expansion cone segments, 1700a, 1700b, 1700c, 1700d, 1700e, and 1700f.

Referring to Fig. 20i, an embodiment of an expansion cone segment assembly 1800 includes interlocking expansion cone segments, 1800a, 1800b, 1800c, 1800d, 1800e, and 1800f.

Referring to Fig. 20j, an embodiment of an expansion cone segment assembly 1900 includes interlocking expansion cone segments, 1900a, 1900b, 1900c, 1900d, 1900e, and 1900f.

Referring to Fig. 20k, an embodiment of an expansion cone segment assembly 2000 includes interlocking expansion cone segments, 2000a, 2000b, 2000c, 2000d, 2000e, and 2000f.

Referring to Fig. 20l, an embodiment of an expansion cone segment assembly 2100 includes interlocking expansion cone segments, 2100a, 2100b, 2100c, 2100d, 2100e, and 2100f.

Referring to Fig. 20m, an embodiment of an expansion cone segment assembly 2200 includes interlocking expansion cone segments, 2200a, 2200b, 2200c, 2200d, 2200e, and 2200f.

The expansion cone segment assemblies 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 1900, 2000, 2100, and 2200 provide enhanced operational properties such as, for example, efficient radial expansion of expandable tubular members and durability during operation.

In several alternative embodiments, the design and operational features of the apparatus 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 1900, 2000, 2100, and 2200 may be combined, in whole or in part, and/or the design and operational elements of the apparatus 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 1900, 2000, 2100, and 2200 may be interspersed among each other.

In several alternative embodiments, the apparatus 200, 300, 400, 500, 600, 700, 800, 900, and 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 1900, 2000, 2100, and 2200 may be used to form or repair wellbore casings, pipelines, or structural supports.

In several alternative embodiments, the apparatus 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 1900, 2000, 2100, and 2200 include two or more expansion cone segments that may be movably support and guided on a tapered expansion cone support body that may, for example, be conical, or may be a multi-sided body.

In several alternative embodiments, the design and operation of the apparatus 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 1900, 2000, 2100, and 2200 are provided substantially as disclosed in one or more of the following: (1) U.S. patent application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, (2) U.S. patent application serial no. 09/510,913, attorney docket no. 25791.7.02, filed on 2/23/2000, (3) U.S. patent application serial no. 09/502,350, attorney docket no. 25791.8.02, filed on 2/10/2000, (4) U.S. patent application serial no. 09/440,338, attorney docket no. 25791.9.02, filed on 11/15/1999, (5) U.S. patent application serial no. 09/523,460, attorney docket no. 25791.11.02, filed on 3/10/2000, (6) U.S. patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, (7) U.S. patent application serial no. 09/511,941, attorney docket no. 25791.16.02, filed on 2/24/2000, (8) U.S. patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, (9) U.S. patent application serial no. 09/559,122, attorney docket no. 25791.23.02, filed on 4/26/2000, (10) PCT patent application serial no. PCT/US00/18635, attorney docket no. 25791.25.02, filed on 7/9/2000, (11) U.S. provisional patent application serial no. 60/162,671, attorney docket no. 25791.27, filed on 11/1/1999, (12) U.S. provisional

patent application serial no. 60/154,047, attorney docket no. 25791.29, filed on 9/16/1999, (13) U.S. provisional patent application serial no. 60/159,082, attorney docket no. 25791.34, filed on 10/12/1999, (14) U.S. provisional patent application serial no. 60/159,039, attorney docket no. 25791.36, filed on 10/12/1999, (15) U.S. provisional patent application serial no. 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999, (16) U.S. provisional patent application serial no. 60/212,359, attorney docket no. 25791.38, filed on 6/19/2000, (17) U.S. provisional patent application serial no. 60/165,228, attorney docket no. 25791.39, filed on 11/12/1999; (18) U.S. provisional patent application serial no. 60/221,443, attorney docket no. 25791.45, filed on 7/28/2000, (19) U.S. provisional patent application serial no. 60/221,645, attorney docket no. 25791.46, filed on 7/28/2000, (20) U.S. provisional patent application serial no. 60/233,638, attorney docket no. 25791.47, filed on 9/18/2000, (21) U.S. provisional patent application serial no. 60/237,334, attorney docket no. 25791.48, filed on 10/2/2000, (22) U.S. provisional patent application serial no. 60/270,007, attorney docket no. 25791.50, filed on 2/20/2001; and (23) U.S. provisional patent application serial no. 60/262,434, attorney docket no. 25791.51, filed on 1/17/2001; and (24) U.S. provisional patent application serial no. 60/259,486, attorney docket no. 25791.52, filed on 1/3/2001, the disclosures of which are incorporated herein by reference.

An apparatus for radially expanding a tubular member has been described that includes a tubular support member that includes a first tubular support body defining a longitudinal passage, a first lug coupled to and extending from the first tubular support body in the radial direction, a second lug coupled to and extending from the first tubular support body in the radial direction, and an expansion cone support body coupled to the first tubular support body. The expansion cone support body includes an N-sided tapered tubular support member, wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot. N expansion cone segments are movably coupled to the expansion cone support body, each including an expansion cone segment body including arcuate conical outer surfaces, a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body, and a second T-shaped retaining member coupled to the expansion cone segment body. A split ring collar assembly is movably coupled to the exterior of the tubular support member that includes a second tubular support body defining N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments, and an L-shaped retaining member coupled to the second tubular support body. A first drag block

assembly is movably coupled to the tubular support member that includes a first drag block body defining a slot for receiving and mating with the L-shaped retaining member of the split ring collar, and a first J-shaped slot for receiving the first lug, and one or more first drag blocks coupled to the first drag block body. A second drag block assembly is movably coupled to the tubular support member that includes a second drag block body defining a second J-shaped slot for receiving the second lug, and one or more second drag blocks coupled to the second drag block body. First and second packer cups are coupled to the tubular support member between the first and second drag block assemblies.

An apparatus for radially expanding a tubular member has also been described that includes a tubular support member that includes a first tubular support body defining a longitudinal passage, a first flange coupled to the first tubular support body, a second flange coupled to the first tubular support body, a first tapered flange coupled to the first tubular support body, a second tapered flange coupled to the first tubular support body, and an expansion cone support body coupled to the first tubular support body. The expansion cone support body includes an N-sided tapered tubular support member, wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot. N expansion cone segments are movably coupled to the expansion cone support body, each including an expansion cone segment body including arcuate conical outer surfaces, a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body, and a second T-shaped retaining member coupled to the expansion cone segment body. A split ring collar is movably coupled to the exterior of the tubular support member that includes a second tubular support body that defines N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments, and an L-shaped retaining member coupled to the second tubular support body. A first collet assembly is movably coupled to the tubular support member that includes a first tubular sleeve that defines a slot for receiving and mating with the L-shaped retaining member of the split ring collar, a first counterbore for receiving the first flange, and a first radial passage, a first spring received within the first counterbore, a first retaining ring received within the first counterbore, a first load transfer pin coupled to the first retaining ring and extending through the first radial passage, a second tubular sleeve coupled to the first load transfer pin, a first resilient collet coupled to the second tubular sleeve and positioned above the first tapered flange, and a third tubular sleeve coupled to the first resilient collet. A second collet

assembly is movably coupled to the tubular support member that includes a fourth tubular sleeve that defines a second counterbore for receiving the second flange, and a second radial passage, a second spring received within the second counterbore, a second retaining ring received within the second counterbore, a second load transfer pin coupled to the second retaining ring and extending through the second radial passage, a fifth tubular sleeve coupled to the second load transfer pin, a second resilient collet coupled to the fifth tubular sleeve and positioned above the second tapered flange, and a sixth tubular sleeve coupled to the second resilient collet. First and second packer cups coupled to the tubular support member between the first and second collet assemblies.

An apparatus for radially expanding a tubular member has also been described that includes a tubular support member that includes a first tubular support body defining a longitudinal passage, a first radial passage defined in the first tubular support body fluidicly coupled to the longitudinal passage, a first flange coupled to the first tubular support body, a second flange coupled to the first tubular support body, a first tapered flange coupled to the first tubular support body, a second tapered flange coupled to the first tubular support body, and an expansion cone support body coupled to the first tubular support body. The expansion cone support body includes an N-sided tapered tubular support member, wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot. N expansion cone segments are movably coupled to the expansion cone support body, each including an expansion cone segment body including arcuate conical outer surfaces, a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body, and a second T-shaped retaining member coupled to the expansion cone segment body. A split ring collar is movably coupled to the exterior of the tubular support member that includes a second tubular support body that defines N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments, and an L-shaped retaining member coupled to the second tubular support body. A first dog assembly is movably coupled to the tubular support member that includes a first tubular sleeve that defines a slot for receiving and mating with the L-shaped retaining member of the split ring collar, a first counterbore for receiving the first flange, and a second radial passage, a first spring received within the first counterbore, a first retaining ring received within the first counterbore, a first load transfer pin coupled to the first retaining ring and extending through the second radial passage, and a second tubular sleeve coupled to the first

load transfer pin that defines a second counterbore for receiving the first tubular sleeve, a first resilient dog coupled to the second tubular sleeve and positioned adjacent to the first tapered flange. A second dog assembly is movably coupled to the tubular support member that includes a third tubular sleeve that defines a second counterbore for receiving the second flange, a third radial passage, and a fourth radial passage fluidicly coupled to the first radial passage, a second spring received within the second counterbore, a second retaining ring received within the second counterbore, a second load transfer pin coupled to the second retaining ring and extending through the third radial passage, a fourth tubular sleeve coupled to the second load transfer pin, and a second resilient dog coupled to the fourth tubular sleeve and positioned adjacent to the second tapered flange. First and second packer cups are coupled to the tubular support member between the first and second dog assemblies.

An apparatus for radially expanding a tubular member has also been described that includes a tubular support member that includes a first tubular support body defining a longitudinal passage including a throat passage, a first radial passage defined in the first tubular support body fluidicly coupled to the longitudinal passage, a first flange coupled to the first tubular support body, a second flange coupled to the first tubular support body that defines a second radial passage defined in the second flange fluidicly coupled to the longitudinal passage, a tapered flange coupled to the first tubular support body, and an expansion cone support body coupled to the first tubular support body. The expansion cone support body includes an N-sided tapered tubular support member, wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot. N expansion cone segments are movably coupled to the expansion cone support body, each including an expansion cone segment body including arcuate conical outer surfaces, a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body, and a second T-shaped retaining member coupled to the expansion cone segment body. A split ring collar is movably coupled to the exterior of the tubular support member that includes a second tubular support body that defines N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments, and an L-shaped retaining member coupled to the second tubular support body. A dog assembly is movably coupled to the tubular support member that includes a first tubular sleeve that defines a slot for receiving and mating with the L-shaped retaining member of the split ring collar, a first counterbore for receiving the first flange, and a third radial passage, a spring received

within the first counterbore, a retaining ring received within the first counterbore, a load transfer pin coupled to the retaining ring and extending through the third radial passage, a second tubular sleeve coupled to the first load transfer pin that defines a first counterbore for receiving the first tubular sleeve, a second counterbore for receiving and mating with the tapered flange, and includes a third flange that defines a third counterbore for receiving the second flange, a fourth counterbore for receiving the second flange, and a fourth radial passage, and a resilient dog coupled to the second tubular sleeve and positioned adjacent to the tapered flange. First and second packer cups are coupled to the tubular support member between the resilient dog and the third flange.

An adjustable expansion cone assembly has also been described that includes a tubular support member that includes a tubular support body and an expansion cone support body coupled to the tubular support body. The expansion cone support body includes an N-sided tapered tubular support member, wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot. N expansion cone segments are movably coupled to the expansion cone support body, each including an expansion cone segment body including arcuate conical outer surfaces, a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body, and a second T-shaped retaining member coupled to the expansion cone segment body. A split ring collar is movably coupled to the exterior of the tubular support member that includes a second tubular support body that defines N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments, and an L-shaped retaining member coupled to the second tubular support body. A tubular actuating sleeve is movably coupled to the tubular support member that includes a third tubular support body that defines a slot for receiving and mating with the L-shaped retaining member of the split ring collar.

An adjustable expansion cone assembly has also been described that includes a tubular support member that includes a first tubular support body, and an expansion cone support body coupled to the tubular support body. The expansion cone support body includes a tapered tubular support member defining N stepped slots. An expansion cone assembly is movably coupled to the tubular support member that includes a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot, and N expansion cone segments extending from the second tubular support member. Each expansion cone segment includes a resilient

collet coupled to the second tubular support member, an expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces, and a retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the stepped slots of the expansion cone support body. A split ring collar is movably coupled to the exterior of the tubular support member that includes a third tubular support body, a first L-shaped retaining member coupled to the third tubular support body for mating with the L-shaped slot of the second tubular support body of the expansion cone assembly, and a second L-shaped retaining member coupled to the third tubular body. A tubular actuating sleeve is movably coupled to the tubular support member that includes a third tubular support body that defines a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

An adjustable expansion cone assembly has also been described that includes a tubular support member that includes a first tubular support body, and an expansion cone support body coupled to the tubular support body. The expansion cone support body includes a tapered tubular support member defining N slots. An expansion cone assembly is movably coupled to the tubular support member that includes a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot, and N expansion cone segments extending from the second tubular support member. Each expansion cone segment includes a resilient collet coupled to the second tubular support member, an expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces, and a retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body. A split ring collar is movably coupled to the exterior of the tubular support member that includes a third tubular support body, a first L-shaped retaining member coupled to the third tubular support body for mating with the L-shaped slot of the second tubular support body, and a second L-shaped retaining member coupled to the third tubular support body. A tubular actuating sleeve is movably coupled to the tubular support member that includes a third tubular support body that defines a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

An adjustable expansion cone assembly has also been described that includes a tubular support member that includes a first tubular support body, and an expansion cone support body coupled to the tubular support body. The expansion cone support body includes a tapered tubular support member defining N slots. An expansion cone assembly is movably coupled to the tubular support member that includes a second

tubular support body movably coupled to the first tubular support body defining an L-shaped slot, N/2 first expansion cone segments extending from the second tubular support member, and N/2 second expansion cone segments extending from the second tubular member. Each first expansion cone segment includes a first resilient collet coupled to the second tubular support member, a first expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces, and a first retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body. Each second expansion cone segment includes a second resilient collet coupled to the second tubular support member, a second expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces, and a second retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body. The second expansion cone segments overlap and are interleaved with the first expansion cone segments. A split ring collar is movably coupled to the exterior of the tubular support member that includes a third tubular support body, a first L-shaped retaining member coupled to the third tubular support body for mating with L-shaped slot of the second tubular support body, and a second L-shaped retaining member coupled to the third tubular support body. A tubular actuating sleeve is movably coupled to the tubular support member that includes a third tubular support body that defines a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

An adjustable expansion cone assembly has also been described that includes a tubular support member that includes a first tubular support body, and an expansion cone support body coupled to the first tubular support body. The expansion cone support body includes an N-sided tapered tubular support member, wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot. N/2 first expansion cone segments are movably coupled to the expansion cone support body, each including a first expansion cone segment body including arcuate conical outer surfaces, a first T-shaped retaining member coupled to the first expansion cone segment body for movably coupling the first expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body, and a second T-shaped retaining member coupled to the first expansion cone segment body. N/2 second expansion cone segments are also movably coupled to the expansion cone support body, each including a second expansion cone segment body including arcuate conical outer surfaces, a third T-shaped retaining member coupled to the

second expansion cone segment body for movably coupling the second expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body, and a fourth T-shaped retaining member coupled to the expansion cone segment body. The first and second expansion cone segments are interleaved. The first expansion cone segment bodies are complementary shaped with respect to the second expansion cone segment bodies. A split ring collar assembly is movably coupled to the exterior of the tubular support member that includes a second tubular support body that defines N T-shaped slots for movably receiving corresponding ones of the second and fourth T-shaped retaining members of the interleaved first and second expansion cone segments, and an L-shaped retaining member coupled to the second tubular support body. A tubular actuating sleeve movably coupled to the tubular support member that includes a third tubular support body that defines a slot for receiving and mating with the L-shaped retaining member of the split ring collar.

An apparatus for radially expanding a tubular member has also been described that includes a tubular support member that includes a first tubular support body defining a longitudinal passage, a first lug coupled to and extending from the first tubular support body in the radial direction, and a second lug coupled to and extending from the first tubular support body in the radial direction. An adjustable expansion cone assembly is movably coupled to the tubular support member. A first drag block assembly is movably coupled to the tubular support member that includes a first drag block body coupled to the adjustable expansion cone assembly that defines: a first J-shaped slot for receiving the first lug, and one or more first drag blocks coupled to the first drag block body. A second drag block assembly is movably coupled to the tubular support member that includes a second drag block body that defines: a second J-shaped slot for receiving the second lug, and one or more second drag blocks coupled to the second drag block body. First and second packer cups are coupled to the tubular support member between the first and second drag block assemblies.

An apparatus for radially expanding a tubular member has also been described that includes a tubular support member that includes a first tubular support body defining a longitudinal passage, a first flange coupled to the first tubular support body, a second flange coupled to the first tubular support body, a first tapered flange coupled to the first tubular support body, and a second tapered flange coupled to the first tubular support body. An adjustable expansion cone assembly is movably coupled to the tubular support member. A first collet assembly is movably coupled to the tubular support member that includes a first tubular sleeve coupled to the adjustable expansion cone assembly and defines a first counterbore for receiving the first flange, and a first

radial passage, a first spring received within the first counterbore, a first retaining ring received within the first counterbore, a first load transfer pin coupled to the first retaining ring and extending through the first radial passage, a second tubular sleeve coupled to the first load transfer pin, a first resilient collet coupled to the second tubular sleeve and positioned above the first tapered flange, and a third tubular sleeve coupled to the first resilient collet. A second collet assembly is movably coupled to the tubular support member that includes a fourth tubular sleeve that defines: a second counterbore for receiving the second flange, and a second radial passage, a second spring received within the second counterbore, a second retaining ring received within the second counterbore, a second load transfer pin coupled to the second retaining ring and extending through the second radial passage, a fifth tubular sleeve coupled to the second load transfer pin, a second resilient collet coupled to the fifth tubular sleeve and positioned above the second tapered flange, and a sixth tubular sleeve coupled to the second resilient collet. First and second packer cups are coupled to the tubular support member between the first and second collet assemblies.

An apparatus for radially expanding a tubular member has also been described that includes a tubular support member that includes a first tubular support body defining a longitudinal passage, a first radial passage defined in the first tubular support body fluidicly coupled to the longitudinal passage, a first flange coupled to the first tubular support body, a second flange coupled to the first tubular support body, a first tapered flange coupled to the first tubular support body, and a second tapered flange coupled to the first tubular support body. An adjustable expansion cone assembly is movably coupled to the tubular support member. A first dog assembly is movably coupled to the tubular support member that includes a first tubular sleeve coupled to the adjustable expansion cone assembly that defines: a first counterbore for receiving the first flange, and a second radial passage, a first spring received within the first counterbore, a first retaining ring received within the first counterbore, a first load transfer pin coupled to the first retaining ring and extending through the second radial passage, a second tubular sleeve coupled to the first load transfer pin that defines: a second counterbore for receiving the first tubular sleeve, a first resilient dog coupled to the second tubular sleeve and positioned adjacent to the first tapered flange. A second dog assembly is movably coupled to the tubular support member that includes a third tubular sleeve that defines a second counterbore for receiving the second flange, a third radial passage, and a fourth radial passage fluidicly coupled to the first radial passage, a second spring received within the second counterbore, a second retaining ring received within the second counterbore, a second load transfer pin coupled to the

second retaining ring and extending through the third radial passage, a fourth tubular sleeve coupled to the second load transfer pin, a second resilient dog coupled to the fourth tubular sleeve and positioned adjacent to the second tapered flange. First and second packer cups are coupled to the tubular support member between the first and second dog assemblies.

An apparatus for radially expanding a tubular member has also been described that includes a tubular support member that includes a first tubular support body defining a longitudinal passage including a throat passage, a first radial passage defined in the first tubular support body fluidicly coupled to the longitudinal passage, a first flange coupled to the first tubular support body, and a second flange coupled to the first tubular support body that defines: a second radial passage defined in the second flange fluidicly coupled to the longitudinal passage. An adjustable expansion cone assembly is movably coupled to the tubular support member. A dog assembly is movably coupled to the tubular support member that includes a first tubular sleeve coupled to the adjustable expansion cone assembly that defines a first counterbore for receiving the first flange, and a third radial passage, a spring received within the first counterbore, a retaining ring received within the first counterbore, a load transfer pin coupled to the retaining ring and extending through the third radial passage, a second tubular sleeve coupled to the first load transfer pin that defines: a first counterbore for receiving the first tubular sleeve, a second counterbore for receiving and mating with the tapered flange, and includes a third flange that defines a third counterbore for receiving the second flange, a fourth counterbore for receiving the second flange, and a fourth radial passage, and a resilient dog coupled to the second tubular sleeve and positioned adjacent to the tapered flange. First and second packer cups are coupled to the tubular support member between the resilient dog and the third flange.

An apparatus for radially expanding a tubular member has also been described that includes a tubular support member, an adjustable expansion cone assembly movably coupled to the tubular support member, and means for adjusting the adjustable expansion cone assembly.

An adjustable expansion cone assembly has also been described that includes a tubular support member. An adjustable expansion cone is movably coupled to the tubular support member that includes a plurality of expansion cone segments, and means for guiding the expansion cone segments on the tubular support member. The assembly further includes means for adjusting the adjustable expansion cone.

A method of operating an adjustable expansion cone assembly including a plurality of expansion cone segments has also been described that includes guiding the

expansion cone segments on a tapered body, and controllably displacing the expansion cone segments along the tapered body.

A method of operating an adjustable expansion cone assembly including a plurality of expansion cone segments has also been described that includes guiding the expansion cone segments on a multi-sided tapered body, interlocking the expansion cone segments, and controllably displacing the expansion cone segments along the tapered body.

A method of operating an adjustable expansion cone assembly including a plurality of expansion cone segments has also been described that includes resiliently guiding the expansion cone segments on a multi-sided tapered body, guiding each of the expansion cone segments on opposite sides in the circumferential direction, interlocking the expansion cone segments, and controllably displacing the expansion cone segments along the tapered body.

A method of operating an adjustable expansion cone assembly including a plurality of expansion cone segments has also been described that includes dividing the expansion cone segments into first and second groups of expansion cone segments, interleaving the first and second groups of expansion cone segments, overlapping the first and second groups of expansion cone segments, resiliently guiding the expansion cone segments on a multi-sided tapered body, guiding each of the expansion cone segments on opposite sides in the circumferential direction, and controllably displacing the expansion cone segments along the tapered body.

A method of operating an adjustable expansion cone assembly including a plurality of expansion cone segments has also been described that includes dividing the expansion cone segments into first and second groups of expansion cone segments, interleaving the first and second groups of expansion cone segments, guiding the expansion cone segments on a multi-sided tapered body, and controllably displacing the expansion cone segments along the tapered body while also relatively displacing the first and second groups of expansion cone segments in opposite directions.

A method of plastically deforming and radially expanding an expandable tubular member using an apparatus including a tubular support member, an adjustable expansion cone assembly movably coupled to the tubular support member, and an actuator movably coupled to the tubular support member for adjusting the adjustable expansion cone assembly, has also been described that includes coupling a first end of the expandable tubular member to a tubular structure, locking the actuator to the tubular support member of the apparatus, inserting the apparatus into the first end of

the expandable tubular member, moving the actuator and the adjustable expansion cone assembly of the apparatus out of the second end of the expandable tubular member, reinserting the actuator of the apparatus into the second end of the expandable tubular member, unlocking the actuator from the tubular support member of the apparatus, rotating the actuator relative to the tubular support member of the apparatus, and increasing the outside diameter of the adjustable expansion cone assembly by moving the tubular support member relative to the actuator, the adjustable expansion cone assembly and the expandable tubular member, and plastically deforming and radially expanding the expandable tubular member by moving the adjustable expansion cone assembly through the expandable tubular member.

A method of plastically deforming and radially expanding an expandable tubular member using an apparatus including a tubular support member, an adjustable expansion cone assembly movably coupled to the tubular support member, and an actuator movably coupled to the tubular support member for adjusting the adjustable expansion cone assembly, has also been described that includes coupling a first end of the expandable tubular member to a tubular structure, inserting the apparatus into the first end of the expandable tubular member in a first direction, displacing the actuator of the apparatus in a second direction opposite to the first direction, applying a resilient biasing force to the adjustable expansion cone assembly in the second direction, moving the actuator and the adjustable expansion cone assembly of the apparatus out of the second end of the expandable tubular member, reinserting the actuator of the apparatus into the second end of the expandable tubular member in the second direction, increasing the outside diameter of the adjustable expansion cone assembly by displacing the actuator and the adjustable expansion cone assembly relative to the expandable tubular member in the first direction, and plastically deforming and radially expanding the expandable tubular member by moving the adjustable expansion cone assembly through the expandable tubular member in the second direction.

An adjustable expansion cone assembly has also been described that includes a plurality of expansion cone segments, means for guiding the expansion cone segments on a tapered body, and means for controllably displacing the expansion cone segments along the tapered body.

An adjustable expansion cone assembly has also been described that includes a plurality of expansion cone segments, means for guiding the expansion cone segments on a multi-sided tapered body, means for interlocking the expansion cone segments, and means for controllably displacing the expansion cone segments along the tapered body.

An adjustable expansion cone assembly has also been described that includes a plurality of expansion cone segments, means for resiliently guiding the expansion cone segments on a multi-sided tapered body, means for guiding each of the expansion cone segments on opposite sides in the circumferential direction, means for interlocking the expansion cone segments, and means for controllably displacing the expansion cone segments along the tapered body.

An adjustable expansion cone assembly has also been described that includes a plurality of expansion cone segments, means for dividing the expansion cone segments into first and second groups of expansion cone segments, means for interleaving the first and second groups of expansion cone segments, means for overlapping the first and second groups of expansion cone segments, means for resiliently guiding the expansion cone segments on a multi-sided tapered body, means for guiding each of the expansion cone segments on opposite sides in the circumferential direction, and means for controllably displacing the expansion cone segments along the tapered body.

An adjustable expansion cone assembly has also been described that includes a plurality of expansion cone segments, means for dividing the expansion cone segments into first and second groups of expansion cone segments, means for interleaving the first and second groups of expansion cone segments, means for guiding the expansion cone segments on a multi-sided tapered body, and means for controllably displacing the expansion cone segments along the tapered body while also relatively displacing the first and second groups of expansion cone segments in opposite directions.

An apparatus for plastically deforming and radially expanding an expandable tubular member has also been described that includes a tubular support member, an adjustable expansion cone assembly movably coupled to the tubular support member, means for actuating the adjustable expansion cone assembly, means for locking the actuator to the tubular support member of the apparatus, means for unlocking the actuator from the tubular support member of the apparatus, and means for increasing the outside diameter of the adjustable expansion cone assembly by moving the tubular support member relative to the actuator, the adjustable expansion cone assembly, and the expandable tubular member.

An apparatus for plastically deforming and radially expanding an expandable tubular member has also been described that includes a tubular support member, an adjustable expansion cone assembly movably coupled to the tubular support member, means for actuating the adjustable expansion cone assembly, means for displacing the

actuator of the apparatus in a first direction, means for applying a resilient biasing force to the adjustable expansion cone assembly when the actuator is displaced in the first direction, and means for increasing the outside diameter of the adjustable expansion cone assembly by displacing the actuator and the adjustable expansion cone assembly relative to the expandable tubular member in a second direction opposite to the first direction.

Although illustrative embodiments of the invention have been shown and described, a wide range of modification, changes and substitution is contemplated in the foregoing disclosure. In some instances, some features of the present invention may be employed without a corresponding use of the other features. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention.

Claims

1. An apparatus for radially expanding a tubular member, comprising:
a tubular support member;
an adjustable expansion device movably coupled to the tubular support member; and
means for adjusting the adjustable expansion device.

2. The apparatus of claim 1, wherein the means for adjusting the adjustable expansion device comprises:
frictional means for adjusting the adjustable expansion device.

3. The apparatus of claim 1, wherein the means for adjusting the adjustable expansion device comprises:
resilient means for adjusting the adjustable expansion device.

4. The apparatus of claim 1, wherein the adjustable expansion device comprises:
a plurality of expansion segments; and
means for guiding the expansion segments on the tubular support member.

5 The apparatus of claim 4, wherein the adjustable expansion device further comprises:
means for interlocking the expansion segments.

6. The apparatus of claim 4, wherein the means for adjusting the adjustable expansion device comprises:
resilient means for supporting the expansion segments.

7. The apparatus of claim 4, wherein the expansion segments include first and second interleaved groups of expansion segments.

8. The apparatus of claim 7, wherein the means for adjusting the adjustable expansion device comprises:
means for displacing the first and second interleaved groups of expansion segments in opposite directions.

9. A method of operating an adjustable expansion device comprising a plurality of expansion segments, comprising:

guiding the expansion segments on a tapered body; and

controllably displacing the expansion segments along the tapered body.

10. The method of claim 9, further comprising:

resiliently guiding the expansion segments on the tapered body.

11. The method of claim 9, further comprising:

interlocking the expansion segments.

12. The method of claim 9, further comprising:

dividing the expansion segments into first and second groups of expansion segments; and

interleaving the first and second groups of expansion segments.

13. The method of claim 12, further comprising:

overlapping the first and second groups of expansion segments.

14. The method of claim 12, wherein controllably displacing the expansion segments along the tapered body comprises:

displacing the first and second interleaved groups of expansion segments in opposite directions.

15. The method of claim 9, further comprising interlocking the expansion segments.

16. The method of claim 9, further comprising:

resiliently guiding the expansion segments on a multi-sided tapered body;

guiding each of the expansion segments on opposite sides in the circumferential direction; and

interlocking the expansion segments.

17. The method of claim 9, further comprising:

dividing the expansion segments into first and second groups of expansion segments;

interleaving the first and second groups of expansion segments;

overlapping the first and second groups of expansion segments;

resiliently guiding the expansion segments on a multi-sided tapered body; and

guiding each of the expansion segments on opposite sides in the circumferential direction.

18. The method of claim 9, further comprising:

dividing the expansion segments into first and second groups of expansion segments;

interleaving the first and second groups of expansion segments;

guiding the expansion segments on a multi-sided tapered body; and

controllably displacing the expansion segments along the tapered body while also relatively displacing the first and second groups of expansion segments in opposite directions.

19. The apparatus of claim 4, further comprising:

means for guiding the expansion segments on a tapered body; and

means for controllably displacing the expansion segments along the tapered body.

20. The apparatus of claim 19, further comprising:

means for resiliently guiding the expansion segments on the tapered body.

21. The apparatus of claim 19, further comprising:

means for interlocking the expansion segments.

22. The apparatus of claim 19, further comprising:

means for dividing the expansion segments into first and second groups of expansion segments; and

means for interleaving the first and second groups of expansion segments.

23. The apparatus of claim 22, further comprising:

means for overlapping the first and second groups of expansion segments.

24. The apparatus of claim 22, wherein the means for controllably displacing the expansion segments along the tapered body comprises:

means for displacing the first and second interleaved groups of expansion

segments in opposite directions.

25. The apparatus of claim 4, further comprising:

means for guiding the expansion segments on a multi-sided tapered body;

means for interlocking the expansion segments; and

means for controllably displacing the expansion segments along the tapered body.

26. The apparatus of claim 4, further comprising:

means for resiliently guiding the expansion segments on a multi-sided tapered body;

means for guiding each of the expansion segments on opposite sides in the circumferential direction;

means for interlocking the expansion segments; and

means for controllably displacing the expansion segments along the tapered body.

27. The apparatus of claim 4, further comprising:

means for dividing the expansion segments into first and second groups of expansion segments;

means for interleaving the first and second groups of expansion segments;

means for overlapping the first and second groups of expansion segments;

means for resiliently guiding the expansion segments on a multi-sided tapered body;

means for guiding each of the expansion segments on opposite sides in the circumferential direction; and

means for controllably displacing the expansion segments along the tapered body.

28. The apparatus of claim 4, further comprising:

means for dividing the expansion segments into first and second groups of expansion segments;

means for interleaving the first and second groups of expansion segments;

means for guiding the expansion segments on a multi-sided tapered body; and

means for controllably displacing the expansion segments along the tapered body while also relatively displacing the first and second groups of expansion

segments in opposite directions.

1. An apparatus for radially expanding a tubular member, comprising:

a tubular support member comprising:

a first tubular support body defining a longitudinal passage;

a first lug coupled to and extending from the first tubular support body in the radial direction;

a second lug coupled to and extending from the first tubular support body in the radial direction; and

an expansion cone support body coupled to the first tubular support body comprising:

an N-sided tapered tubular support member;

wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot;

N expansion cone segments movably coupled to the expansion cone support body, each comprising:

an expansion cone segment body including arcuate conical outer surfaces;

a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body; and

a second T-shaped retaining member coupled to the expansion cone segment body;

a split ring collar assembly movably coupled to the exterior of the tubular support member comprising:

a second tubular support body defining:

N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments; and

an L-shaped retaining member coupled to the second tubular support body;

a first drag block assembly movably coupled to the tubular support member that comprises:

a first drag block body defining:

a slot for receiving and mating with the L-shaped retaining member of the split ring collar; and

a first J-shaped slot for receiving the first lug; and

one or more first drag blocks coupled to the first drag block body;

a second drag block assembly movably coupled to the tubular support member that comprises:

a second drag block body defining:

a second J-shaped slot for receiving the second lug; and

one or more second drag blocks coupled to the second drag block body; and

first and second packer cups coupled to the tubular support member between the first and second drag block assemblies.

2. An apparatus for radially expanding a tubular member, comprising:

a tubular support member comprising:

a first tubular support body defining a longitudinal passage;

a first flange coupled to the first tubular support body;

a second flange coupled to the first tubular support body;

a first tapered flange coupled to the first tubular support body;

a second tapered flange coupled to the first tubular support body; and

an expansion cone support body coupled to the first tubular support body comprising:

an N-sided tapered tubular support member;

wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot;

N expansion cone segments movably coupled to the expansion cone support body, each comprising:

an expansion cone segment body including arcuate conical outer surfaces;

a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body; and

a second T-shaped retaining member coupled to the expansion cone segment body;

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a second tubular support body that defines:

N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments; and

an L-shaped retaining member coupled to the second tubular support body;

a first collet assembly movably coupled to the tubular support member that comprises:

a first tubular sleeve defining:

a slot for receiving and mating with the L-shaped retaining member of the split ring collar;

a first counterbore for receiving the first flange; and

a first radial passage;

a first spring received within the first counterbore;

a first retaining ring received within the first counterbore;

a first load transfer pin coupled to the first retaining ring and extending through the first radial passage;

a second tubular sleeve coupled to the first load transfer pin;

a first resilient collet coupled to the second tubular sleeve and positioned above the first tapered flange; and

a third tubular sleeve coupled to the first resilient collet;

a second collet assembly movably coupled to the tubular support member that comprises:

a fourth tubular sleeve defining:

a second counterbore for receiving the second flange; and

a second radial passage;

a second spring received within the second counterbore;

a second retaining ring received within the second counterbore;

a second load transfer pin coupled to the second retaining ring and extending through the second radial passage;

a fifth tubular sleeve coupled to the second load transfer pin;

a second resilient collet coupled to the fifth tubular sleeve and positioned above the second tapered flange; and

a sixth tubular sleeve coupled to the second resilient collet; and

first and second packer cups coupled to the tubular support member between the first and second collet assemblies.

3. An apparatus for radially expanding a tubular member, comprising:

a tubular support member comprising:

a first tubular support body defining a longitudinal passage;

a first radial passage defined in the first tubular support body fluidicly coupled to the longitudinal passage;

a first flange coupled to the first tubular support body;

a second flange coupled to the first tubular support body;

a first tapered flange coupled to the first tubular support body;

a second tapered flange coupled to the first tubular support body; and

an expansion cone support body coupled to the first tubular support body comprising:

an N-sided tapered tubular support member;

wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot;

N expansion cone segments movably coupled to the expansion cone support body, each comprising:

an expansion cone segment body including arcuate conical outer surfaces;

a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body; and

a second T-shaped retaining member coupled to the expansion cone segment body;

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a second tubular support body defining:

N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments; and

an L-shaped retaining member coupled to the second tubular support body;

a first dog assembly movably coupled to the tubular support member that comprises:

a first tubular sleeve defining:

a slot for receiving and mating with the L-shaped retaining member of the split ring collar;

a first counterbore for receiving the first flange; and

a second radial passage;

a first spring received within the first counterbore;

a first retaining ring received within the first counterbore;

a first load transfer pin coupled to the first retaining ring and extending through the second radial passage;

a second tubular sleeve coupled to the first load transfer pin defining:

a second counterbore for receiving the first tubular sleeve;

a first resilient dog coupled to the second tubular sleeve and positioned adjacent to the first tapered flange;

a second dog assembly movably coupled to the tubular support member that comprises:

a third tubular sleeve defining:

a second counterbore for receiving the second flange;

a third radial passage; and

a fourth radial passage fluidicly coupled to the first radial passage;

a second spring received within the second counterbore;

a second retaining ring received within the second counterbore;

a second load transfer pin coupled to the second retaining ring and extending through the third radial passage;

a fourth tubular sleeve coupled to the second load transfer pin;

a second resilient dog coupled to the fourth tubular sleeve and positioned adjacent to the second tapered flange; and

first and second packer cups coupled to the tubular support member between the first and second dog assemblies.

4. An apparatus for radially expanding a tubular member, comprising:

a tubular support member comprising:

a first tubular support body defining a longitudinal passage including a throat passage;

a first radial passage defined in the first tubular support body fluidicly coupled to the longitudinal passage;

a first flange coupled to the first tubular support body;

a second flange coupled to the first tubular support body defining:

a second radial passage defined in the second flange fluidicly coupled to the longitudinal passage;

a tapered flange coupled to the first tubular support body; and

an expansion cone support body coupled to the first tubular support body comprising:

an N-sided tapered tubular support member;

wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot;

N expansion cone segments movably coupled to the expansion cone support body, each comprising:

an expansion cone segment body including arcuate conical outer surfaces;

a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body; and

a second T-shaped retaining member coupled to the expansion cone segment body;

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a second tubular support body defining:

N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments; and

an L-shaped retaining member coupled to the second tubular support body;

a dog assembly movably coupled to the tubular support member that comprises:

a first tubular sleeve defining:

a slot for receiving and mating with the L-shaped retaining member of the split ring collar;

a first counterbore for receiving the first flange; and

a third radial passage;

a spring received within the first counterbore;

a retaining ring received within the first counterbore;

a load transfer pin coupled to the retaining ring and extending through the third radial passage;

a second tubular sleeve coupled to the first load transfer pin that defines:

a first counterbore for receiving the first tubular sleeve;

a second counterbore for receiving and mating with the tapered flange; and

comprises:

a third flange defining:

a third counterbore for receiving the second flange;

a fourth counterbore for receiving the second flange; and

a fourth radial passage; and

a resilient dog coupled to the second tubular sleeve and positioned adjacent to the tapered flange; and

first and second packer cups coupled to the tubular support member between the resilient dog and the third flange.

5. An adjustable expansion cone assembly, comprising:

a tubular support member comprising:

a tubular support body; and

an expansion cone support body coupled to the tubular support body comprising:

an N-sided tapered tubular support member;

wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot;

N expansion cone segments movably coupled to the expansion cone support body, each comprising:

an expansion cone segment body including arcuate conical outer surfaces;

a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body; and

a second T-shaped retaining member coupled to the expansion cone segment body;

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a second tubular support body defining:

N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments; and

an L-shaped retaining member coupled to the second tubular support body; and

a tubular actuating sleeve movably coupled to the tubular support member that comprises:

a third tubular support body defining:

a slot for receiving and mating with the L-shaped retaining member of the split ring collar.

6. An adjustable expansion cone assembly, comprising:

a tubular support member comprising:

a first tubular support body; and

an expansion cone support body coupled to the tubular support body comprising:

a tapered tubular support member defining N stepped slots;

an expansion cone assembly movably coupled to the tubular support member comprising:

a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot; and

N expansion cone segments extending from the second tubular support member, each expansion cone segment comprising:

a resilient collet coupled to the second tubular support member;

an expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the

stepped slots of the expansion cone support body;

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a third tubular support body;

a first L-shaped retaining member coupled to the third tubular support body for mating with the L-shaped slot of the second tubular support body of the expansion cone assembly; and

a second L-shaped retaining member coupled to the third tubular body; and

a tubular actuating sleeve movably coupled to the tubular support member that comprises:

a third tubular support body defining:

a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

7. An adjustable expansion cone assembly, comprising:

a tubular support member comprising:

a first tubular support body; and

an expansion cone support body coupled to the tubular support body comprising:

a tapered tubular support member defining N slots;

an expansion cone assembly movably coupled to the tubular support member comprising:

a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot; and

N expansion cone segments extending from the second tubular support member, each expansion cone segment comprising:

a resilient collet coupled to the second tubular support member;

an expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a retaining member coupled to the expansion cone segment body for movably coupling the expansion

cone segment body to a corresponding one of the slots of the expansion cone support body;

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a third tubular support body;

a first L-shaped retaining member coupled to the third tubular support body for mating with the L-shaped slot of the second tubular support body; and

a second L-shaped retaining member coupled to the third tubular support body; and

a tubular actuating sleeve movably coupled to the tubular support member that comprises:

a third tubular support body defining:

a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

8. An adjustable expansion cone assembly, comprising:

a tubular support member comprising:

a first tubular support body; and

an expansion cone support body coupled to the tubular support body comprising:

a tapered tubular support member defining N slots;

an expansion cone assembly movably coupled to the tubular support member comprising:

a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot; and

N/2 first expansion cone segments extending from the second tubular support member, each first expansion cone segment comprising:

a first resilient collet coupled to the second tubular support member;

a first expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a first retaining member coupled to the expansion cone segment body for movably coupling the expansion

cone segment body to a corresponding one of the slots of the expansion cone support body;

N/2 second expansion cone segments extending from the second tubular support member, each second expansion cone segment comprising:

a second resilient collet coupled to the second tubular support member;

a second expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a second retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body;

wherein the second expansion cone segments overlap and are interleaved with the first expansion cone segments;

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a third tubular support body;

a first L-shaped retaining member coupled to the third tubular support body for mating with L-shaped slot of the second tubular support body; and

a second L-shaped retaining member coupled to the third tubular support body; and

a tubular actuating sleeve movably coupled to the tubular support member that comprises:

a third tubular support body defining:

a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

9. An adjustable expansion cone assembly, comprising:

a tubular support member comprising:

a first tubular support body; and

an expansion cone support body coupled to the first tubular support body comprising:

an N-sided tapered tubular support member;

wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot;

N/2 first expansion cone segments movably coupled to the expansion cone support body, each comprising:

a first expansion cone segment body including arcuate conical outer surfaces;

a first T-shaped retaining member coupled to the first expansion cone segment body for movably coupling the first expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body; and

a second T-shaped retaining member coupled to the first expansion cone segment body;

N/2 second expansion cone segments movably coupled to the expansion cone support body, each comprising:

a second expansion cone segment body including arcuate conical outer surfaces;

a third T-shaped retaining member coupled to the second expansion cone segment body for movably coupling the second expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body; and

a fourth T-shaped retaining member coupled to the expansion cone segment body;

wherein the first and second expansion cone segments are interleaved;

wherein the first expansion cone segment bodies are complementary shaped with respect to the second expansion cone segment bodies;

a split ring collar assembly movably coupled to the exterior of the tubular support member comprising:

a second tubular support body defining:

N T-shaped slots for movably receiving corresponding ones of the second and fourth T-shaped retaining members of the interleaved first and second expansion cone segments; and

an L-shaped retaining member coupled to the second tubular support body; and

a tubular actuating sleeve movably coupled to the tubular support member that comprises:

a third tubular support body defining:

a slot for receiving and mating with the L-shaped retaining member of the split ring collar.

10. An apparatus for radially expanding a tubular member, comprising:

a tubular support member comprising:

a first tubular support body defining a longitudinal passage;

a first lug coupled to and extending from the first tubular support body in the radial direction; and

a second lug coupled to and extending from the first tubular support body in the radial direction;

an adjustable expansion cone assembly movably coupled to the tubular support member;

a first drag block assembly movably coupled to the tubular support member that comprises:

a first drag block body coupled to the adjustable expansion cone assembly defining:

a first J-shaped slot for receiving the first lug; and

one or more first drag blocks coupled to the first drag block body;

a second drag block assembly movably coupled to the tubular support member that comprises:

a second drag block body defining:

a second J-shaped slot for receiving the second lug; and

one or more second drag blocks coupled to the second drag block body; and

first and second packer cups coupled to the tubular support member between the first and second drag block assemblies.

11. The apparatus of claim 10, wherein the tubular support member further comprises:

an expansion cone support body coupled to the first tubular support body comprising:

an N-sided tapered tubular support member;

wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot;

wherein the adjustable expansion cone assembly comprises:

N expansion cone segments movably coupled to the expansion cone support body, each comprising:

an expansion cone segment body including arcuate conical outer surfaces;

a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body; and

a second T-shaped retaining member coupled to the expansion cone segment body; and

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a second tubular support body defining:

N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments; and

an L-shaped retaining member coupled to the second tubular support body; and

wherein the first drag block body further defines:

a slot for receiving and mating with the L-shaped retaining member of the split ring collar.

12. The apparatus of claim 10, wherein the tubular support member further comprises:

an expansion cone support body coupled to the tubular support body comprising:

a tapered tubular support member defining N stepped slots;

wherein the adjustable expansion cone assembly comprises:

an expansion cone assembly movably coupled to the tubular support member comprising:

a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot; and

N expansion cone segments extending from the second tubular support member, each expansion cone segment comprising:

a resilient collet coupled to the second tubular support member;

an expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the stepped slots of the expansion cone support body; and

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a third tubular support body:

a first L-shaped retaining member coupled to the third tubular support body for mating with the L-shaped slot of the second tubular support body; and

a second L-shaped retaining member coupled to the third tubular support member;

wherein the first drag block body further defines:

a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

13. The apparatus of claim 10, wherein the tubular support member further comprises:

an expansion cone support body coupled to the first tubular support body comprising:

a tapered tubular support member defining N slots;

wherein the adjustable expansion cone assembly comprises:

an expansion cone assembly movably coupled to the tubular support member comprising:

a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot; and

N expansion cone segments extending from the second tubular support member, each expansion cone segment comprising:

a resilient collet coupled to the second tubular support member;

an expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body; and

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a third tubular support body;

a first L-shaped retaining member coupled to the third tubular support body for mating with L-shaped slot of the second tubular support body; and

a second L-shaped retaining member coupled to the third tubular support body;

wherein the first drag block body further defines:

a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

14. The apparatus of claim 10, wherein the tubular support member further comprises:

an expansion cone support body coupled to the tubular support body comprising:

a tapered tubular support member defining N slots;

wherein the adjustable expansion cone assembly comprises:

an expansion cone assembly movably coupled to the tubular support member comprising:

a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot; and

N/2 first expansion cone segments extending from the second tubular support member, each first expansion cone segment comprising:

a first resilient collet coupled to the second tubular support member;

a first expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a first retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body;

N/2 second expansion cone segments extending from the second tubular support member, each second expansion cone segment comprising:

a second resilient collet coupled to the second tubular support member;

a second expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a second retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body;

wherein the second expansion cone segments overlap and are interleaved with the first expansion cone segments; and

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a third tubular support body;

a first L-shaped retaining member coupled to the third tubular support body for mating with the L-shaped slot of the second tubular support body; and

a second L-shaped retaining member coupled to the third tubular support body;

wherein the first drag block body further defines:

a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

15. The apparatus of claim 10, wherein the tubular support member further comprises:

an expansion cone support body coupled to the first tubular support body comprising:

an N-sided tapered tubular support member;

wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot;

wherein the adjustable expansion cone assembly comprises:

N/2 first expansion cone segments movably coupled to the expansion cone support body, each comprising:

a first expansion cone segment body including arcuate conical outer surfaces;

a first T-shaped retaining member coupled to the first expansion cone segment body for movably coupling the first expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body; and

a second T-shaped retaining member coupled to the first expansion cone segment body;

N/2 second expansion cone segments movably coupled to the expansion cone support body, each comprising:

a second expansion cone segment body including arcuate conical outer surfaces;

a third T-shaped retaining member coupled to the second expansion cone segment body for movably coupling the second expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body; and

a fourth T-shaped retaining member coupled to the expansion cone segment body;

wherein the first and second expansion cone segments are interleaved;
wherein the first expansion cone segment bodies are complementary shaped with respect to the second expansion cone segment bodies; and
a split ring collar assembly movably coupled to the exterior of the tubular support member comprising:
a second tubular support body defining:
N T-shaped slots for movably receiving corresponding ones of the second and fourth T-shaped retaining members of the interleaved first and second expansion cone segments; and
an L-shaped retaining member coupled to the second tubular support body; and
wherein the first drag block body further defines:
a slot for receiving and mating with the L-shaped retaining member of the split ring collar.

16. An apparatus for radially expanding a tubular member, comprising:
a tubular support member comprising:
a first tubular support body defining a longitudinal passage;
a first flange coupled to the first tubular support body;
a second flange coupled to the first tubular support body;
a first tapered flange coupled to the first tubular support body; and
a second tapered flange coupled to the first tubular support body;
an adjustable expansion cone assembly movably coupled to the tubular support member;
a first collet assembly movably coupled to the tubular support member that comprises:
a first tubular sleeve coupled to the adjustable expansion cone assembly and defining:
a first counterbore for receiving the first flange; and
a first radial passage;
a first spring received within the first counterbore;
a first retaining ring received within the first counterbore;
a first load transfer pin coupled to the first retaining ring and extending through the first radial passage;

a second tubular sleeve coupled to the first load transfer pin;

a first resilient collet coupled to the second tubular sleeve and positioned above the first tapered flange; and

a third tubular sleeve coupled to the first resilient collet;

a second collet assembly movably coupled to the tubular support member that comprises:

a fourth tubular sleeve defining:

a second counterbore for receiving the second flange; and

a second radial passage;

a second spring received within the second counterbore;

a second retaining ring received within the second counterbore;

a second load transfer pin coupled to the second retaining ring and extending through the second radial passage;

a fifth tubular sleeve coupled to the second load transfer pin;

a second resilient collet coupled to the fifth tubular sleeve and positioned above the second tapered flange; and

a sixth tubular sleeve coupled to the second resilient collet; and

first and second packer cups coupled to the tubular support member between the first and second collet assemblies.

17. The apparatus of claim 16, wherein the tubular support member further comprises:

an expansion cone support body coupled to the first tubular support body comprising:

an N-sided tapered tubular support member;

wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot;

wherein the adjustable expansion cone assembly comprises:

N expansion cone segments movably coupled to the expansion cone support body, each comprising:

an expansion cone segment body including arcuate conical outer surfaces;

a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body; and

a second T-shaped retaining member coupled to the expansion cone segment body; and

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a second tubular support body defining:

N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments; and

an L-shaped retaining member coupled to the second tubular support body; and

wherein the first tubular sleeve of the first collet assembly further defines:

a slot for receiving and mating with the L-shaped retaining member of the split ring collar.

18. The apparatus of claim 16, wherein the tubular support member further comprises:

an expansion cone support body coupled to the tubular support body comprising:

a tapered tubular support member defining N stepped slots;

wherein the adjustable expansion cone assembly comprises:

an expansion cone assembly movably coupled to the tubular support member comprising:

a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot; and

N expansion cone segments extending from the second tubular support member, each expansion cone segment comprising:

a resilient collet coupled to the second tubular support member;

an expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the stepped slots of the expansion cone support body; and

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a third tubular support body:

a first L-shaped retaining member coupled to the third tubular support body for mating with the L-shaped slot of the second tubular support body; and

a second L-shaped retaining member coupled to the third tubular support member;

wherein the first tubular sleeve of the first collet assembly further defines:

a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

19. The apparatus of claim 16, wherein the tubular support member further comprises:

an expansion cone support body coupled to the first tubular support body comprising:

a tapered tubular support member defining N slots;

wherein the adjustable expansion cone assembly comprises:

an expansion cone assembly movably coupled to the tubular support member comprising:

a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot; and

N expansion cone segments extending from the second tubular support member, each expansion cone segment comprising:

a resilient collet coupled to the second tubular support member;

an expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body; and

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a third tubular support body;

a first L-shaped retaining member coupled to the third tubular support body for mating with L-shaped slot of the second tubular support body; and

a second L-shaped retaining member coupled to the third tubular support body;

wherein the first tubular sleeve of the first collet assembly further defines:

a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

20. The apparatus of claim 16, wherein the tubular support member further comprises:

an expansion cone support body coupled to the tubular support body comprising:

a tapered tubular support member defining N slots;

wherein the adjustable expansion cone assembly comprises:

an expansion cone assembly movably coupled to the tubular support member comprising:

a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot; and

N/2 first expansion cone segments extending from the second tubular support member, each first expansion cone segment comprising:

a first resilient collet coupled to the second tubular support member;

a first expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a first retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body;

N/2 second expansion cone segments extending from the second tubular support member, each second expansion cone segment comprising:

a second resilient collet coupled to the second tubular support member;

a second expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a second retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body;

wherein the second expansion cone segments overlap and are interleaved with the first expansion cone segments; and

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a third tubular support body;

a first L-shaped retaining member coupled to the third tubular support body for mating with the L-shaped slot of the second tubular support body; and

a second L-shaped retaining member coupled to the third tubular support body;

wherein the first tubular sleeve of the first collet assembly further defines:

a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

21. The apparatus of claim 16, wherein the tubular support member further comprises:

an expansion cone support body coupled to the first tubular support body comprising:

an N-sided tapered tubular support member;

wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot;

wherein the adjustable expansion cone assembly comprises:

N/2 first expansion cone segments movably coupled to the expansion cone support body, each comprising:

a first expansion cone segment body including arcuate conical outer surfaces;

a first T-shaped retaining member coupled to the first expansion cone segment body for movably coupling the first expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body; and

a second T-shaped retaining member coupled to the first expansion cone segment body;

N/2 second expansion cone segments movably coupled to the expansion cone support body, each comprising:

a second expansion cone segment body including arcuate conical outer surfaces;

a third T-shaped retaining member coupled to the second expansion cone segment body for movably coupling the second expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body; and

a fourth T-shaped retaining member coupled to the expansion cone segment body;

wherein the first and second expansion cone segments are interleaved;

wherein the first expansion cone segment bodies are complementary shaped with respect to the second expansion cone segment bodies; and

a split ring collar assembly movably coupled to the exterior of the tubular support member comprising:

a second tubular support body defining:

N T-shaped slots for movably receiving corresponding ones of the second and fourth T-shaped retaining members of the interleaved first and second expansion cone segments; and

an L-shaped retaining member coupled to the second tubular support body; and

wherein the first tubular sleeve of the first collet assembly further defines:

a slot for receiving and mating with the L-shaped retaining member of the split ring collar.

22. An apparatus for radially expanding a tubular member, comprising:

a tubular support member comprising:

a first tubular support body defining a longitudinal passage;

a first radial passage defined in the first tubular support body fluidicly coupled to the longitudinal passage;

a first flange coupled to the first tubular support body;

a second flange coupled to the first tubular support body;

a first tapered flange coupled to the first tubular support body; and

a second tapered flange coupled to the first tubular support body;

an adjustable expansion cone assembly movably coupled to the tubular support member;

a first dog assembly movably coupled to the tubular support member that comprises:

a first tubular sleeve coupled to the adjustable expansion cone assembly defining:

a first counterbore for receiving the first flange; and

a second radial passage;

a first spring received within the first counterbore;

a first retaining ring received within the first counterbore;

a first load transfer pin coupled to the first retaining ring and extending through the second radial passage;

a second tubular sleeve coupled to the first load transfer pin defining:

a second counterbore for receiving the first tubular sleeve;

a first resilient dog coupled to the second tubular sleeve and positioned adjacent to the first tapered flange;

a second dog assembly movably coupled to the tubular support member that comprises:

a third tubular sleeve defining:

a second counterbore for receiving the second flange;

a third radial passage; and

a fourth radial passage fluidicly coupled to the first radial passage;

a second spring received within the second counterbore;

a second retaining ring received within the second counterbore;

a second load transfer pin coupled to the second retaining ring and extending through the third radial passage;

a fourth tubular sleeve coupled to the second load transfer pin;

a second resilient dog coupled to the fourth tubular sleeve and positioned adjacent to the second tapered flange; and

first and second packer cups coupled to the tubular support member between the first and second dog assemblies.

23. The apparatus of claim 22, wherein the tubular support member further comprises:

an expansion cone support body coupled to the first tubular support body comprising:

an N-sided tapered tubular support member;

wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot;

wherein the adjustable expansion cone assembly comprises:

N expansion cone segments movably coupled to the expansion cone support body, each comprising:

an expansion cone segment body including arcuate conical outer surfaces;

a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body; and

a second T-shaped retaining member coupled to the expansion cone segment body; and

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a second tubular support body defining:

N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments; and

an L-shaped retaining member coupled to the second tubular support body; and

wherein the first tubular sleeve of the first dog assembly further defines:

a slot for receiving and mating with the L-shaped retaining member of the split ring collar.

24. The apparatus of claim 22, wherein the tubular support member further comprises:

an expansion cone support body coupled to the tubular support body comprising:

a tapered tubular support member defining N stepped slots;

wherein the adjustable expansion cone assembly comprises:

an expansion cone assembly movably coupled to the tubular support member comprising:

a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot; and

N expansion cone segments extending from the second tubular support member, each expansion cone segment comprising:

a resilient collet coupled to the second tubular support member;

an expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the stepped slots of the expansion cone support body; and

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a third tubular support body:

a first L-shaped retaining member coupled to the third tubular support body for mating with the L-shaped slot of the second tubular support body; and

a second L-shaped retaining member coupled to the third tubular support member; and

wherein the first tubular sleeve of the first dog assembly further defines:

a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

25. The apparatus of claim 22, wherein the tubular support member further comprises:

an expansion cone support body coupled to the first tubular support body comprising:

a tapered tubular support member defining N slots;

wherein the adjustable expansion cone assembly comprises:

an expansion cone assembly movably coupled to the tubular support member comprising:

a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot; and

N expansion cone segments extending from the second tubular support member, each expansion cone segment comprising:

a resilient collet coupled to the second tubular support member;

an expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body; and

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a third tubular support body;

a first L-shaped retaining member coupled to the third tubular support body for mating with L-shaped slot of the second tubular support body; and

a second L-shaped retaining member coupled to the third tubular support body; and

wherein the first tubular sleeve of the first dog assembly further defines:

a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

26. The apparatus of claim 22, wherein the tubular support member further comprises:

an expansion cone support body coupled to the tubular support body comprising:

a tapered tubular support member defining N slots;

wherein the adjustable expansion cone assembly comprises:

an expansion cone assembly movably coupled to the tubular support member comprising:

a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot; and

N/2 first expansion cone segments extending from the second tubular support member, each first expansion cone segment comprising:

a first resilient collet coupled to the second tubular support member;

a first expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a first retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body;

N/2 second expansion cone segments extending from the second tubular support member, each second expansion cone segment comprising:

a second resilient collet coupled to the second tubular support member;

a second expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a second retaining member coupled to the expansion cone segment body for movably

coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body;

wherein the second expansion cone segments overlap and are interleaved with the first expansion cone segments; and

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a third tubular support body;

a first L-shaped retaining member coupled to the third tubular support body for mating with the L-shaped slot of the second tubular support body; and

a second L-shaped retaining member coupled to the third tubular support body; and

wherein the first tubular sleeve of the first dog assembly further defines:

a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

27. The apparatus of claim 22, wherein the tubular support member further comprises:

an expansion cone support body coupled to the first tubular support body comprising:

an N-sided tapered tubular support member;

wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot;

wherein the adjustable expansion cone assembly comprises:

N/2 first expansion cone segments movably coupled to the expansion cone support body, each comprising:

a first expansion cone segment body including arcuate conical outer surfaces;

a first T-shaped retaining member coupled to the first expansion cone segment body for movably coupling the first expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body; and

a second T-shaped retaining member coupled to the first expansion cone segment body;

N/2 second expansion cone segments movably coupled to the expansion cone support body, each comprising:

a second expansion cone segment body including arcuate conical outer surfaces;

a third T-shaped retaining member coupled to the second expansion cone segment body for movably coupling the second expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body; and

a fourth T-shaped retaining member coupled to the expansion cone segment body;

wherein the first and second expansion cone segments are interleaved;

wherein the first expansion cone segment bodies are complementary shaped with respect to the second expansion cone segment bodies; and

a split ring collar assembly movably coupled to the exterior of the tubular support member comprising:

a second tubular support body defining:

N T-shaped slots for movably receiving corresponding ones of the second and fourth T-shaped retaining members of the interleaved first and second expansion cone segments; and

an L-shaped retaining member coupled to the second tubular support body; and

wherein the first tubular sleeve of the first dog assembly further defines:

a slot for receiving and mating with the L-shaped retaining member of the split ring collar.

28. An apparatus for radially expanding a tubular member, comprising:

a tubular support member comprising:

a first tubular support body defining a longitudinal passage including a throat passage;

a first radial passage defined in the first tubular support body fluidicly coupled to the longitudinal passage;

a first flange coupled to the first tubular support body;

a second flange coupled to the first tubular support body defining:

a second radial passage defined in the second flange fluidicly coupled to the longitudinal passage; and

an adjustable expansion cone assembly movably coupled to the tubular support member;

a dog assembly movably coupled to the tubular support member that comprises:

a first tubular sleeve coupled to the adjustable expansion cone assembly defining:

a first counterbore for receiving the first flange; and

a third radial passage;

a spring received within the first counterbore;

a retaining ring received within the first counterbore;

a load transfer pin coupled to the retaining ring and extending through the third radial passage;

a second tubular sleeve coupled to the first load transfer pin that defines:

a first counterbore for receiving the first tubular sleeve;

a second counterbore for receiving and mating with the tapered flange; and

comprises:

a third flange defining:

a third counterbore for receiving the second flange;

a fourth counterbore for receiving the second flange; and

a fourth radial passage; and

a resilient dog coupled to the second tubular sleeve and positioned adjacent to the tapered flange; and

first and second packer cups coupled to the tubular support member between the resilient dog and the third flange.

29. The apparatus of claim 28, wherein the tubular support member further comprises:

an expansion cone support body coupled to the first tubular support body comprising:

an N-sided tapered tubular support member;

wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot;

wherein the adjustable expansion cone assembly comprises:

N expansion cone segments movably coupled to the expansion cone support body, each comprising:

an expansion cone segment body including arcuate conical outer surfaces;

a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body; and

a second T-shaped retaining member coupled to the expansion cone segment body; and

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a second tubular support body defining:

N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments; and

an L-shaped retaining member coupled to the second tubular support body; and

wherein the first tubular sleeve of the dog assembly further defines:

a slot for receiving and mating with the L-shaped retaining member of the split ring collar.

30. The apparatus of claim 28, wherein the tubular support member further comprises:

an expansion cone support body coupled to the tubular support body comprising:

a tapered tubular support member defining N stepped slots;

wherein the adjustable expansion cone assembly comprises:

an expansion cone assembly movably coupled to the tubular support member comprising:

a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot; and

N expansion cone segments extending from the second tubular support member, each expansion cone segment comprising:

a resilient collet coupled to the second tubular support member;

an expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the stepped slots of the expansion cone support body; and

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a third tubular support body:

a first L-shaped retaining member coupled to the third tubular support body for mating with the L-shaped slot of the second tubular support body; and

a second L-shaped retaining member coupled to the third tubular support member; and

wherein the first tubular sleeve of the dog assembly further defines:

a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

31. The apparatus of claim 28, wherein the tubular support member further comprises:

an expansion cone support body coupled to the first tubular support body comprising:

a tapered tubular support member defining N slots;

wherein the adjustable expansion cone assembly comprises:

an expansion cone assembly movably coupled to the tubular support member comprising:

a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot; and

N expansion cone segments extending from the second tubular support member, each expansion cone segment comprising:

a resilient collet coupled to the second tubular support member;

an expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body; and

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a third tubular support body;

a first L-shaped retaining member coupled to the third tubular support body for mating with L-shaped slot of the second tubular support body; and

a second L-shaped retaining member coupled to the third tubular support body; and

wherein the first tubular sleeve of the dog assembly further defines:

a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

32. The apparatus of claim 28, wherein the tubular support member further comprises:

an expansion cone support body coupled to the tubular support body comprising:

a tapered tubular support member defining N slots;

wherein the adjustable expansion cone assembly comprises:

an expansion cone assembly movably coupled to the tubular support member comprising:

a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot; and

N/2 first expansion cone segments extending from the second tubular support member, each first expansion cone segment comprising:

a first resilient collet coupled to the second tubular support member;

a first expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a first retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body;

N/2 second expansion cone segments extending from the second tubular support member, each second expansion cone segment comprising:

a second resilient collet coupled to the second tubular support member;

a second expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces; and

a second retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body;

wherein the second expansion cone segments overlap and are interleaved with the first expansion cone segments; and

a split ring collar movably coupled to the exterior of the tubular support member comprising:

a third tubular support body;

a first L-shaped retaining member coupled to the third tubular support body for mating with the L-shaped slot of the second tubular support body; and

a second L-shaped retaining member coupled to the third tubular support body; and

wherein the first tubular sleeve of the dog assembly further defines:

a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

33. The apparatus of claim 28, wherein the tubular support member further comprises:

an expansion cone support body coupled to the first tubular support body comprising:

an N-sided tapered tubular support member;

wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot;

wherein the adjustable expansion cone assembly comprises:

N/2 first expansion cone segments movably coupled to the expansion cone support body, each comprising:

a first expansion cone segment body including arcuate conical outer surfaces;

a first T-shaped retaining member coupled to the first expansion cone segment body for movably coupling the first expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body; and

a second T-shaped retaining member coupled to the first expansion cone segment body;

N/2 second expansion cone segments movably coupled to the expansion cone support body, each comprising:

a second expansion cone segment body including arcuate conical outer surfaces;

a third T-shaped retaining member coupled to the second expansion cone segment body for movably coupling the second expansion cone segment body to a

corresponding one of the T-shaped slots of the expansion cone support body; and

a fourth T-shaped retaining member coupled to the expansion cone segment body;

wherein the first and second expansion cone segments are interleaved;

wherein the first expansion cone segment bodies are complementary shaped with respect to the second expansion cone segment bodies; and

a split ring collar assembly movably coupled to the exterior of the tubular support member comprising:

a second tubular support body defining:

N T-shaped slots for movably receiving corresponding ones of the second and fourth T-shaped retaining members of the interleaved first and second expansion cone segments; and

an L-shaped retaining member coupled to the second tubular support body; and

wherein the first tubular sleeve of the dog assembly further defines:

a slot for receiving and mating with the L-shaped retaining member of the split ring collar.

34. An apparatus for radially expanding a tubular member, comprising:

a tubular support member;

an adjustable expansion cone assembly movably coupled to the tubular support member; and

means for adjusting the adjustable expansion cone assembly.

35. The apparatus of claim 34, wherein the means for adjusting the adjustable expansion cone assembly comprises:

frictional means for adjusting the adjustable expansion cone assembly.

36. The apparatus of claim 34, wherein the means for adjusting the adjustable expansion cone assembly comprises:

resilient means for adjusting the adjustable expansion cone assembly.

37. An adjustable expansion cone assembly, comprising:

a tubular support member;

an adjustable expansion cone movably coupled to the tubular support member, comprising:

a plurality of expansion cone segments; and

means for guiding the expansion cone segments on the tubular support member; and

means for adjusting the adjustable expansion cone.

38. The adjustable expansion cone assembly of claim 37, wherein the adjustable expansion cone further comprises:

means for interlocking the expansion cone segments.

39. The adjustable expansion cone assembly of claim 37, wherein the means for adjusting the adjustable expansion cone comprises:

resilient means for supporting the expansion cone segments.

40. The adjustable expansion cone assembly of claim 37, wherein the expansion cone segments include first and second interleaved groups of expansion cone segments.

41. The adjustable expansion cone assembly of claim 40, wherein the means for adjusting the adjustable expansion cone comprises:

means for displacing the first and second interleaved groups of expansion cone segments in opposite directions.

42. A method of operating an adjustable expansion cone assembly comprising a plurality of expansion cone segments, comprising:

guiding the expansion cone segments on a tapered body; and

controllably displacing the expansion cone segments along the tapered body.

43. The method of claim 42, further comprising:

resiliently guiding the expansion cone segments on the tapered body.

44. The method of claim 42, further comprising:

interlocking the expansion cone segments.

45. The method of claim 42, further comprising:
dividing the expansion cone segments into first and second groups of expansion cone segments; and
interleaving the first and second groups of expansion cone segments.

46. The method of claim 45, further comprising:
overlapping the first and second groups of expansion cone segments.

47. The method of claim 45, wherein controllably displacing the expansion cone segments along the tapered body comprises:
displacing the first and second interleaved groups of expansion cone segments in opposite directions.

48. A method of operating an adjustable expansion cone assembly comprising a plurality of expansion cone segments, comprising:

guiding the expansion cone segments on a multi-sided tapered body;
interlocking the expansion cone segments; and
controllably displacing the expansion cone segments along the tapered body.

49. A method of operating an adjustable expansion cone assembly comprising a plurality of expansion cone segments, comprising:
resiliently guiding the expansion cone segments on a multi-sided tapered body;
guiding each of the expansion cone segments on opposite sides in the circumferential direction;
interlocking the expansion cone segments; and
controllably displacing the expansion cone segments along the tapered body.

50. A method of operating an adjustable expansion cone assembly comprising a plurality of expansion cone segments, comprising:
dividing the expansion cone segments into first and second groups of expansion cone segments;
interleaving the first and second groups of expansion cone segments;
overlapping the first and second groups of expansion cone segments;
resiliently guiding the expansion cone segments on a multi-sided tapered body;

guiding each of the expansion cone segments on opposite sides in the circumferential direction; and

controllably displacing the expansion cone segments along the tapered body.

51. A method of operating an adjustable expansion cone assembly comprising a plurality of expansion cone segments, comprising:

dividing the expansion cone segments into first and second groups of expansion cone segments;

interleaving the first and second groups of expansion cone segments;

guiding the expansion cone segments on a multi-sided tapered body; and

controllably displacing the expansion cone segments along the tapered body while also relatively displacing the first and second groups of expansion cone segments in opposite directions.

52. A method of plastically deforming and radially expanding an expandable tubular member using an apparatus comprising a tubular support member, an adjustable expansion cone assembly movably coupled to the tubular support member, and an actuator movably coupled to the tubular support member for adjusting the adjustable expansion cone assembly, comprising:

coupling a first end of the expandable tubular member to a tubular structure;

locking the actuator to the tubular support member of the apparatus;

inserting the apparatus into the first end of the expandable tubular member;

moving the actuator and the adjustable expansion cone assembly of the apparatus out of the second end of the expandable tubular member;

reinserting the actuator of the apparatus into the second end of the expandable tubular member;

unlocking the actuator from the tubular support member of the apparatus;

rotating the actuator relative to the tubular support member of the apparatus; and

increasing the outside diameter of the adjustable expansion cone assembly by moving the tubular support member relative to the actuator, the adjustable expansion cone assembly, and the expandable tubular member; and

plastically deforming and radially expanding the expandable tubular member by moving the adjustable expansion cone assembly through the expandable tubular member.

53. The method of claim 52, wherein the tubular support member includes one or more lugs; wherein the actuator includes one or more corresponding retaining slots; and wherein locking comprises positioning the lugs into the corresponding retaining slots.

54. The method of claim 52, wherein the tubular support member includes one or more lugs; wherein the actuator includes one or more corresponding retaining slots; and wherein unlocking comprises positioning the lugs out of engagement with corresponding retaining slots.

55. The method of claim 52, wherein moving the tubular support member relative to the actuator, the adjustable expansion cone assembly, and the expandable tubular member comprises:

the actuator frictionally engaging the expandable tubular member.

56. The method of claim 52, wherein moving the adjustable expansion cone assembly through the expandable tubular member comprises:

pulling the adjustable expansion cone through the expandable tubular member.

57. The method of claim 52, further comprising:

fluidicly sealing the interface between the tubular support member of the apparatus and the expandable tubular member;

wherein moving the adjustable expansion cone assembly through the expandable tubular member comprises:

injecting a pressurized fluid into the tubular support member.

58. A method of plastically deforming and radially expanding an expandable tubular member using an apparatus comprising a tubular support member, an adjustable expansion cone assembly movably coupled to the tubular support member, and an actuator movably coupled to the tubular support member for adjusting the adjustable expansion cone assembly, comprising:

coupling a first end of the expandable tubular member to a tubular structure;

inserting the apparatus into the first end of the expandable tubular member in a first direction;
displacing the actuator of the apparatus in a second direction opposite to the first direction;
applying a resilient biasing force to the adjustable expansion cone assembly in the second direction;
moving the actuator and the adjustable expansion cone assembly of the apparatus out of the second end of the expandable tubular member;
reinserting the actuator of the apparatus into the second end of the expandable tubular member in the second direction;
increasing the outside diameter of the adjustable expansion cone assembly by displacing the actuator and the adjustable expansion cone assembly relative to the expandable tubular member in the first direction; and
plastically deforming and radially expanding the expandable tubular member by moving the adjustable expansion cone assembly through the expandable tubular member in the second direction.

59. The method of claim 58, wherein displacing the actuator of the apparatus in the second direction comprises:
impacting the actuator with the first end of the expandable tubular member.

60. The method of claim 58, wherein displacing the actuator and the adjustable expansion cone assembly relative to the expandable tubular member in the first direction comprises:
impacting the actuator with the second end of the expandable tubular member.

61. The method of claim 58, wherein moving the adjustable expansion cone assembly through the expandable tubular member comprises:
pulling the adjustable expansion cone through the expandable tubular member.

62. The method of claim 58, further comprising:
fluidicly sealing the interface between the tubular support member of the apparatus and the expandable tubular member;
wherein moving the adjustable expansion cone assembly through the expandable tubular member comprises:
injecting a pressurized fluid into the tubular support member.

63. An adjustable expansion cone assembly, comprising:
a plurality of expansion cone segments;
means for guiding the expansion cone segments on a tapered body; and
means for controllably displacing the expansion cone segments along the tapered body.

64. The assembly of claim 63, further comprising:
means for resiliently guiding the expansion cone segments on the tapered body.

65. The assembly of claim 63, further comprising:
means for interlocking the expansion cone segments.

66. The assembly of claim 63, further comprising:
means for dividing the expansion cone segments into first and second groups of expansion cone segments; and
means for interleaving the first and second groups of expansion cone segments.

67. The assembly of claim 66, further comprising:
means for overlapping the first and second groups of expansion cone segments.

68. The assembly of claim 66, wherein the means for controllably displacing the expansion cone segments along the tapered body comprises:
means for displacing the first and second interleaved groups of expansion cone segments in opposite directions.

69. An adjustable expansion cone assembly, comprising:
a plurality of expansion cone segments;
means for guiding the expansion cone segments on a multi-sided tapered body;
means for interlocking the expansion cone segments; and
means for controllably displacing the expansion cone segments along the tapered body.

70. An adjustable expansion cone assembly, comprising:
a plurality of expansion cone segments;
means for resiliently guiding the expansion cone segments on a multi-sided tapered body;
means for guiding each of the expansion cone segments on opposite sides in the circumferential direction;
means for interlocking the expansion cone segments; and
means for controllably displacing the expansion cone segments along the tapered body.

71. An adjustable expansion cone assembly, comprising:
a plurality of expansion cone segments;
means for dividing the expansion cone segments into first and second groups of expansion cone segments;
means for interleaving the first and second groups of expansion cone segments;
means for overlapping the first and second groups of expansion cone segments;
means for resiliently guiding the expansion cone segments on a multi-sided tapered body;
means for guiding each of the expansion cone segments on opposite sides in the circumferential direction; and
means for controllably displacing the expansion cone segments along the tapered body.

72. An adjustable expansion cone assembly, comprising:
a plurality of expansion cone segments;
means for dividing the expansion cone segments into first and second groups of expansion cone segments;
means for interleaving the first and second groups of expansion cone segments;
means for guiding the expansion cone segments on a multi-sided tapered body; and
means for controllably displacing the expansion cone segments along the tapered body while also relatively displacing the first and second groups of expansion cone segments in opposite directions.

73. An apparatus for plastically deforming and radially expanding an expandable tubular member, comprising:

a tubular support member;

an adjustable expansion cone assembly movably coupled to the tubular support member;

means for actuating the adjustable expansion cone assembly;

means for locking the actuator to the tubular support member of the apparatus;

means for unlocking the actuator from the tubular support member of the apparatus;

means for increasing the outside diameter of the adjustable expansion cone assembly by moving the tubular support member relative to the actuator, the adjustable expansion cone assembly, and the expandable tubular member.

74. The apparatus of claim 73, wherein the tubular support member includes one or more lugs; wherein the actuator includes one or more corresponding retaining slots; and wherein the means for locking comprises positioning the lugs into the corresponding retaining slots.

75. The apparatus of claim 73, wherein the tubular support member includes one or more lugs; wherein the actuator includes one or more corresponding retaining slots; and wherein the means for unlocking comprises positioning the lugs out of engagement with corresponding retaining slots.

76. The method of claim 73, further comprising:

means for fluidicly sealing the interface between the tubular support member of the apparatus and the expandable tubular member.

77. An apparatus for plastically deforming and radially expanding an expandable tubular member, comprising:

a tubular support member;

an adjustable expansion cone assembly movably coupled to the tubular support member;

means for actuating the adjustable expansion cone assembly;

means for displacing the actuator of the apparatus in a first direction;

means for applying a resilient biasing force to the adjustable expansion cone assembly when the actuator is displaced in the first direction;

means for increasing the outside diameter of the adjustable expansion cone assembly by displacing the actuator and the adjustable expansion cone assembly relative to the expandable tubular member in a second direction opposite to the first direction.

78. The apparatus of claim 77, wherein the means for displacing the actuator of the apparatus in the first direction comprises:

means for impacting the actuator.

79. The apparatus of claim 77, wherein the means for displacing the actuator and the adjustable expansion cone assembly relative to the expandable tubular member in the first direction comprises:

means for impacting the actuator.

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Claims searched:	1-28	**Date of search:**	10 January 2005

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X,E	1 and 9 at least	WO 2003/016669 A (Eventure Global Technology) - whole document
X,P	1 and 9 at least	WO 02/059456 A (E2Tech) - whole document
X	1 and 9 at least	US 3785193 A (Kinley et al) - see figs 4-6
X	1 and 9 at least	US 3245471 A (Howard) - see fig 1
X	1 and 9 at least	US 2627891 A (Clark) - see fig 1

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X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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Field of Search:

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E1F

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E21B

The following online and other databases have been used in the preparation of this search report

Online: WPI, EPODOC, JAPIO